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President's Page

Conventional and Unconventional Wisdom

In commenting on the growth of science and the possibility of a 'saturated state of science' in his thought-provoking series of lectures at Yale in the latter part of 1959, Derek J. deS. Price (*Science Since Babylon*, Yale University Press, 1961) remarked that 'Not only is science changing more and more rapidly, it is entering a completely new state. In this new state, our civilization will rise or fall according to the tactics and strategy of our application of our scientific efforts. It is anarchical to decide such issues by merely letting ourselves be ruled by the loudest voices.' Just how these issues will be resolved is not quite clear, but it is almost certain that there is no single mechanism available, or just around the corner, that will do the job. Whatever is to be accomplished will be the sum total of a great number of individuals and of scientific associations such as our own.

There is little doubt that geophysics is participating in the changes to which Dr. Price made reference. The American Geophysical Union has demonstrated a capability for being responsive to those changes. This is evident in the vigor with which it approached the problem of providing an appropriate publication medium for the widening spectrum of scientific contributions in this field, and in the establishment of the Planning Committee on Planetary Science as a focal point in the Union for the rapidly expanding interest in this aspect of the environmental sciences. The success of both of these activities is

ample vindication of the perception, sound thinking, and intelligent planning that preceded their initiation.

But change always carries with it the requirement to adapt to change, and this in turn requires a degree of statesmanship on the part of members, officers, and Council that is every bit as demanding as the statesmanship that is involved in sound and successful innovation. To insure that kind of balance in the allocation of publication space that is responsive both to the needs of the times and to the needs of important groups in the Union, to construct the organizational framework within the AGU which will provide 'a home for planetary sciences' and yet perform the integration of disciplines and sections which is one of the great traditions of the Union—to do these things and to anticipate the needs of the future—will require an uncommon lot of wisdom from all of us.

What is really required, I suppose, is judicious blending of conventional wisdom, as J. K. Galbraith has referred to it, and unconventional wisdom. Stated in other terms, we must balance those things which are acceptable with those things which are relevant. It is inevitable that there will be oscillation in achieving this balance, but here is where the reservoir of good will and unity of purpose that characterizes the AGU may be expected to stand us in good stead.

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Study of the Earth's Deep Interior

Project 'Upper Mantle and Its Effects on Development of the Earth's Crust'

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The classical methods of geology permitted study of the structure of the thinnest surface film of the Earth's crust with a thickness up to several kilometers. Deep drilling and geophysical prospecting methods have expanded somewhat the scope of geological investigations, but nevertheless have not extended them beyond the surface sector of the Earth's crust.

At the same time, no doubts exist that the processes evoking the upheavals and subsidences of the Earth's crust, the wrinkling of its layers into folds, the formation of fissures in it, the genesis of earthquakes, the formation of molten magma, volcanic eruptions, and the formations of magmatic intrusions, occur either in the lower strata of the Earth's crust, that is, on the continents at depths of several tens of kilometers, or, even more often, beneath the Earth's crust at a depth of several hundreds of kilometers, in the upper part of the so-called Earth's mantle.

As yet these processes are practically unknown to us and relative to them there exist either very precarious or poorly based assumptions. Even the chemical and mineral composition of the upper mantle is unknown and existing hypotheses concerning it vary widely.

A study of the processes occurring in the lower parts of the Earth's crust and in the upper mantle has a value quite apart from the merely theoretical. Knowledge of these processes is closely linked with solution of the most urgent practical problems, insofar as with these processes are associated the formation and distribution (in the upper layers of the Earth's crust) of chemical compounds which serve as mineral raw materials. The laws concerning distribution of these materials can not be com-

prehended adequately if we do not study the deep processes that are the primary cause of formation of the materials.

Of course, modern geology, using classical methods, has attained notable successes in understanding the regularities of mineral distribution in the Earth's crust. However, a forecast of mineral distribution presently is based on a combination of purely empirical data and on external analogies. If we could come to know the conditions of formation of magmas of various composition that give rise to the formation and concentration of definite groups of minerals, we could base a practical forecast upon our understanding of the primary cause of the formation of the given minerals. It is scarcely necessary to prove separately that together with the extension of knowledge of the processes in the deep interior, there will be developed a new branch of geology, at least in that part of it which is concerned with problems of movements of the Earth's crust and the formation and displacement of molten magma. In this geology judgments would be based not on a familiarization solely with the external manifestations of processes at a considerable depth, but on a comprehension of the entire nature and the entire mechanism of the processes. The breakthrough which thereby would occur in geology can be compared with the breakthrough in chemistry or in physics which occurred with the discovery of the internal structure of matter.

The present time is most fitting to pay active attention to this problem. Even several years ago, the geophysical methods of study of the Earth's interior were too crude for such questions to be practically raised. In very recent years, we have witnessed an extremely rapid de-

velopment of geophysical methods, caused largely by investigations based on the IGY program. It will suffice to cite the great improvement in methods of deep seismic sounding, the use of long surface seismic waves, leading to the strikingly important discovery of differences in structure of the upper mantle beneath the continents and oceans; the use of rockets and sputniks for studying the Earth's magnetic field, permitting us to choose, from existing hypotheses of the origin of the geomagnetic field, the most likely one; the considerable increase in the precision of gravimetric observations; the discovery of the possibility of using observations of tides in the Earth's crust for studying its structure; the new data on the heat flow in the Earth, affecting in a most important way our understanding of the processes at a considerable depth; the new data on the properties of rocks under conditions of high temperatures and pressures, and many others.

All these achievements, however, are connected with geophysical and geochemical researches which have been conducted separately, without a unified program, without coordination. Therefore numerous results of such investigations are to a considerable degree fortuitous in nature. It is known that no one can build a house by a haphazard tossing of bricks. In any case, such a method of building is not the most economical, rapid or effective. It is necessary to develop a program of research that is aimed at the solution of definite, actual problems in a fixed, rational sequence.

At the same time, we need to use the new techniques for direct penetration into the deep interior of the Earth. We have in mind the use of the most recent technical accomplishment for the organization of very deep drilling. Certainly no geophysical investigative methods are comparable with drilling: only thus can we extract from the depths samples of material, and only in such a fashion will we finally be able to establish reliably the composition and properties of this matter. Boreholes to depths of 15-18 km in the oceans will reveal the entire Earth's crust and the upper layers of the mantle; on the continents, such holes will reveal the lower parts of the granitic layer and clarify what the basalt layer actually is. Such deep holes do not yet exist, but their drilling is within the scope of present technical capabilities.

It is natural, in this period when we have only begun the initial collection of data on the deep structure of the crust and of the upper mantle, that it will be difficult to determine without error the most intelligent program of activities for the immediate future. But undoubtedly it will be necessary to get the most complete data on the differences in the deep structure of various geotectonic zones—on the platforms and on the fold zones of various age, anticlines and sineclises, anticlinoria and synclinoria, on advanced and on intermountain depressions, and also on continents and oceans, on transitional zones from the first to the second, on deep and shallow seas and on island arcs. Simultaneously, we need to obtain data on differences in the deep structure of areas, distinguished by chemism and type of magmatic manifestations. A comparison of such data will permit us not only to represent the contemporary deep structure of various geotectonic and magmatic zones, but also to form conclusions on the nature of the processes transpiring in the deep interior of the Earth. This is possible since various geotectonic and magmatic zones reflect individual stages in the regularly directed development of the Earth's crust. Because of the non-uniformity of the process, the various sections of the Earth's crust at present are at various developmental stages. Comparing the structure of the sections of the Earth's crust (such sections situated at historically successive stages), we shall be able to judge which transformations and displacements of matter should have occurred at a given depth with the transition from one stage to another. Along these lines, certain data have already been derived, describing the processes at a considerable depth in a light which is somewhat unexpected from the standpoint of those views which had been held until quite recently. For instance, there exist regions which, after they had passed the geosynclinal stage of very active development and had become quiescent platforms, again 'came to life' and within their limits the vertical movements of the Earth's crust, its upheavals and subsidences, were renewed with great force and with great range of contrast. These are the so-called zones of tectonic activation. They include, for instance, the Tien-Shan Range. Judging by data of deep seismic sounding, the crust within the limits of

such zones differs from the crust of platforms of enlarged thickness of the basalt layer. Thence we can conclude that the tectonic activation is connected with the melting and rise of great amounts of basalt from the mantle. On the other hand, in geosynclines, upheavals (anticlinoria) are distinguished by increased thickness of granitic layer, while the depressions (synclinoria) are typified by decreased thickness of the same layer, and sometimes even by its complete absence (in the latter event, the sedimentary layers rest directly upon the basalt layer). Moreover, geological data lead us to believe that in a number of cases, at the site of present depression, an upheaval existed earlier beneath which the crust had a structure normal for geosynclinal upheavals, that is, it contained a thick granite layer in its structure. Hence, the transformation of an uplift to a depression was associated with the process, until now not understood by us, but definitely manifested in the decrease in thickness or even complete disappearance of the granite layer of the crust. Similarly, it can be established that the formation of many contemporary deep seas, and at least of many sections of the oceans (and possibly of all oceans as a whole), was also connected with the destruction of the granite layer and with the conversion of the granitic-basalt continental crust to a water-basalt oceanic crust.

For international cooperation (without which the solution of the entire problem will be protracted) to be attained in this study of differences in the deep structure of the geotectonic and magmatic zones, it would be feasible to plan, for example, two or more deep profiles, girdling the Earth along the great-arcs.

Based on the line of these profiles, within a strip several hundred kilometers wide, there could be organized all those geophysical, as well as tectonic and petrological studies, which could serve to clarify the structure of the entire layer of the Earth's crust and of the upper mantle to a depth of several hundred kilometers. In many cases, one could use the results of geophysical investigations already conducted, but these results should be subjected to a new interpretation. The use of seismological methods requires an analysis of already available results

of the recording of many earthquakes. In other cases, additional geophysical studies will be needed. Such profiles would constitute a reference, and using them as a base, one could subsequently extend the investigations to ever broader areas.

Naturally, much attention should be devoted to increasing the resolving ability of the geophysical methods, and above all of deep seismic sounding, which so far has yielded too general a pattern of the deep structure, in many cases not permitting one to grasp the differences in structure among individual special tectonic or magmatic zones.

The development of technology and methods of very deep drilling, and also of observations in boreholes, will demand great creative efforts by scientists and engineers of various fields.

Much attention must be given to laboratory studies of the properties of rocks and minerals under conditions of high temperatures and pressures.

Recognizing the great scientific significance of investigations of processes in the deep interior which are reflected in the structure and movements of the surface section of the Earth's crust, the XII General Assembly of the International Union of Geodesy and Geophysics, convening in the summer of 1960, adopted (as one of its main programs) a research project under the title: 'Upper Mantle and Its Effect on the Earth's Crust.'

Investigations within a 'project of the upper mantle' should be based on the closest coordination of geological, geophysical, geochemical and physical methods. By the same token, through the combination of the sciences indicated, a quite significant step will be made in the direction of creating a unified science of the Earth, composite in its methods. The birth of such a composite Earth science (for it the term 'geonomy' could be proposed) is due, because the over-all problems of the structure and development of the deep parts of the Earth's globe and of the entire Earth will be solved only by combining methods of a number of existing, differentiated sciences, each separately studying the various aspects of the structure and life of our planet.

Oceanography—A Definition for Academic Use¹

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The earliest non-governmental programs in oceanography in the United States—and still the most comprehensive—are those of the Woods Hole Oceanographic Institution and of the Scripps Institution of Oceanography of the University of California. When these were established they were independent of other institutions of science, except administratively, and were physically separated from them. Thus, there was no occasion to define oceanography in relation to the specific activities of other scientific fields.

In recent months increasing thought has been given to the importance of our marine environment and to more effective means of studying it. Oceanography is the center of interest of a committee of the National Academy of Sciences; the President's Science Advisory Committee is deeply concerned with its problems; Congress is considering suitable legislation; and President Kennedy has stated that we have neglected oceanography.

What is oceanography? Where does it fit in relation to other sciences? Who are the oceanographers? These questions might well be asked. Their answers become more and more important as emphasis on the subject increases.

Several recent publications deal with these questions [*Committee on Oceanography*, 1960; *Committee on Education and Recruitment*, 1960; *Fleming*, 1957]. Although each of these is enlightening from one point of view or another, none of them suggests specifically how oceanography fits into the departmental system of organization which is so common on college campuses. The definition to be presented here was made for this particular application. It may have value in other regards.

Prior to 1949, when the Department of Oceanography

was established on the campus at Texas A and M College, there was no existing academic oceanography department with a rounded program in the different aspects of the subject. We probably have the longest experience with such a program of research and training under the full set of categories; biological, chemical, geological, meteorological, and physical oceanography—together with their engineering counterparts—as I outlined them earlier [Leipper, 1950]. Further, it appears that we initiated the tendency in this country toward joint development of oceanographic and meteorological research and training, beginning the full Ph.D. program in meteorology in 1956 and changing the Department name to include meteorology at that time. There is now a strong trend toward the development of similar programs in a number of other institutions. Consideration of the definitions under which we have developed thus may be of general interest and applicability.

Definition of field—Oceanography may be defined as the study of the oceans in all their aspects. The oceans and their bounding media are considered as a unified dynamic system, the study of which may be approached from the points of view, and with the techniques of, the various pertinent basic sciences.

Oceanographer—An oceanographer is a person thoroughly trained in one of the pertinent basic sciences, or in engineering, who has learned to apply his specialty in the marine environment (which requires a combination of principles and methods and a certain body of knowledge unique to oceanography) and who has an interest in and at least an elementary knowledge of each of the marine sciences.

Subdivisions of Oceanography—(a) Biological oceanography is the study of the oceans as they pertain to life in the sea, including both plants and animals.

¹ Contribution from the Department of Oceanography and Meteorology, The Agricultural and Mechanical College of Texas.

(b) Physical oceanography is oceanography which considers primarily ocean waves and water movements, transformations of energy, and the physical characteristics of sea water.

(c) Geological oceanography is oceanography which deals chiefly with the relationships between the land, the ocean bottom, and the oceans, and which includes studies of beach erosion and sedimentation, determination of bottom topography, and the interpretation of marine deposits.

(d) Chemical oceanography is the study of the oceans as a chemical system. It considers the chemical constituents of the sea and the chemical reactions which take place within it. It includes determinations of the amount of various constituents present, development of methods of extraction, and studies of corrosive effects.

(e) Meteorological oceanography is oceanography which involves the winds and weather over the sea, as, for example, the study of ocean waves and currents set up by the wind, or the climate as determined by evaporation and conduction from the sea surface.

Relation of oceanography to the basic sciences and the marine sciences—The oceans, being simply one of the geographical portions of the earth, form a region in which most, if not all, of the basic sciences may apply. For example, the molecular theories of chemistry and physics, the techniques of the calculus and other mathematical subjects, the physiology of marine organisms, and the geological structures underlying the waters, all pertain in ocean analyses. Oceanography thus needs the accumulated knowledge of the basic sciences and of engineering. The application of these fields to the marine environment without extensive modification of their methods or techniques constitutes what may be called marine science. The marine scientist may isolate a problem such as the classification of marine plants and solve it by methods which are standard in the pertinent basic field.

The unification or integration of the marine sciences—together with the addition of a specific body of knowledge about the oceans as such—constitutes *oceanography*. The oceanographer deals with the ocean as a whole, considering the interaction of all the various factors which may be operating simultaneously.

Discussion—In defining oceanography the

key words are those which state that the oceans are considered as a *unified dynamic medium*. A marine scientist, as distinguished from an oceanographer, may not need to consider them thus but may isolate a problem, such as the determination of the chemical contents of a certain bottle of sea water, and work upon it without reference to its source.

A most important characteristic of the oceanographer is his breadth of interest in marine subjects. However, the complexity of problems in oceanography is great and he must also specialize in one aspect of oceanography if he is to make satisfactory progress.

From the point of view of education, the modifying words biological, chemical, etc., as used at Texas A and M College, carry several implications. They imply that the oceanographer in the aspect denoted has a standard background training in that aspect extending when feasible to the M.S. level or beyond, that he continues to study and to maintain contacts in this background science, and that the research which he conducts involves the relationship of this science to oceanography.

For many purposes oceanography is considered a subdivision of geophysics. Some parts of oceanography obviously fall here but the biological phase would not systematically be included. For this reason, among others, there has been a tendency to use 'earth sciences' as a more inclusive grouping which includes oceanography as a component.

In some parts of the world there is a tendency to speak of oceanography as including only the physical and meteorological phases. True, there are some marine problems which may be resolved by considerations lying only within these two areas, such as studies of certain tidal phenomena. However, programs organized under this concept of oceanography would not satisfactorily provide for an effective approach to other problems of the sea, the majority of which involve a close interaction between the life sciences and the physical sciences. It seems that work included entirely within physical and meteorological fields, but concerning the oceans, might more properly be called marine physics than oceanography.

Each of the scientific aspects of oceanography may be considered to have an engineering counterpart where the backgrounds might be re-

spectively: wildlife management or fisheries management (possibly extending the reasoning a little) for biological oceanography; civil, electrical, or mechanical engineering for physical oceanography; geological engineering or petroleum engineering for geological oceanography; chemical engineering for chemical oceanography; and meteorological engineering for meteorological oceanography.

In defining the subdivisions of oceanography there are certain highly important words. For biological oceanography one is 'life in the sea' as opposed, for example, to life *from* the sea. In geological oceanography, dealing 'with *relationships*' or *interactions* should be emphasized. For chemical oceanography the key words may well be '*oceans as a chemical system*.' For physical and meteorological oceanography there seem to be no such terms which readily may be singled out.

It may clarify the definition if all sciences are divided into two categories. First the 'subject' sciences which concern the study of basic laws or principles and secondly the 'object' sciences which concern the study of things. In the object

category with oceanography would then, for example, fall meteorology—the study of the atmosphere, and geology—the study of the solid earth. The 'subject' sciences must provide the basis for all work in these 'object' sciences and yet the properties of the objects to be studied are such that intensive specialized attention must be given them if they are to be understood. Oceanography is a good example of an 'object' science.

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Some Hydrologic Investigations in Africa

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In the arid regions of the tropical zone, surface runoff rarely provides an answer to the problems of water supply. Under prevailing conditions, evaporation (about 13 ft. per year) would absorb the greater part of the water which could be stored in dams. It is none the less necessary to study this form of flow for the following reasons: in the particular case of very deep gorges traditional type reservoirs may be envisaged; knowledge of certain data pertaining to surface hydrology is necessary to the creation of reserves in the sands of river beds; the ground water recharge cannot be studied from the quantitative aspect unless measurements of the various processes of the water cycle are recorded.

If the arid areas are defined as those areas receiving annual rainfall of less than 8 to 12 inches (200 to 300 mm.), it is found that, in tropical Africa, the water-table cannot, in general, be supplied by direct infiltration of rainfall. A necessary condition to such supply is previous concentration of surface runoff, whence the need to study this runoff.

However, such research presents difficulties. Flow takes place in the form of rare floods of short duration; low density of population hinders the organization of a system of permanent observation, and the river beds are constantly changing.

The irregularity of flow defies statistics, and once the watershed exceeds an area of several square kilometers, transposition is difficult because of hydrographic degradation. For these reasons the objectives must be limited. What is the volume of flow in an average year? Throughout what period? What are the characteristics of flow for one wet year of any given frequency? Are there years without flow? What is the approximate volume of flow during heavy spates? Is it possible to obtain an idea of the maximum spate flow? Finally, in the very rare

cases of permanent flow, what is the annual minimum?

The data normally available are too limited to provide answers to these questions. They consist of measurements recorded by a single rain-gauge which are scarcely representative of the area's climate, and more or less incomplete and always qualitative indications of the flow in certain wadis.

It is difficult to remedy this situation, for the low density of population and the lack of any considerable economic activity in such areas do not justify the considerable expenditure required to carry out the necessary research.

South of the Sahara where floods are likely to take place only during a three-month period, from July to September, a particular method of research has given satisfactory results. It is based on the following principles.

During a short period—3 years—rainfall is observed over the whole study area. Records obtained from the Reference Stations provide sufficient data for the study of inter-annual variations in rainfall.

One or two experimental catchments serve for estimating spate flow resulting from each individual storm in the hilliest areas which, in fact, alone supply the water courses.

Extensive study of spate flow of the large water courses provides direct information concerning their hydrological systems. This information is complemented by the results from the experimental catchments.

In practice, three series of operations are undertaken. (a) A general network of rain-gages, mainly comprising long period storage gages, is installed at the beginning of the research project. Whenever possible, the intensity of the individual storms should be determined by rainfall intensity recorders, intensity being a particularly important factor in estimating the volume of surface runoff.

(b) Rainfall and stream flow are observed simultaneously in an experimental catchment particularly representative of the area. Depending on its area, this catchment is equipped with 6 to 12 rainfall gages and 2 rainfall intensity recorders which, moreover, are integrated in the general network. Flow is measured at a river gaging station equipped with a water level recorder. It is sometimes possible to locate the experimental catchment near a large water course. In such cases a river gaging station is installed on the water course facilitating constant observation of flow.

(c) Extensive study is carried out by effecting a series of visits to the area during the season when there is likelihood of storms. Observation of the experimental catchment (or catchments) is also limited to this period. When itineraries cut across the main water courses at several points the marks left by the most recent spates are noted and a series of measurements is taken if the stream is flowing. The rainfall storage gages are visited at the same time. Observation of the level of ponds or reservoirs also provides valuable information. Complementary studies of evaporation and sediment load are effected on the experimental catchment.

The research work is carried out by a senior hydrologist and an assistant. The senior hydrologist carries out an extensive study of the water courses. Such study requires precise measurements and reconstitutions of flow. At the same time the hydrologist checks the raingage network and directs work on the experimental catchment. The assistant's task consists of making observations and taking measurements on the experimental catchment and at the weather station installed there.

Research in these desert areas takes on a special character because of the very difficult conditions existing therein. Transportation is almost always a problem, theft or sabotage of instruments is frequent, and expenditures for research must be kept down to a minimum. Consequently, installations are of a simple nature and equipment is light. For example, the long-period storage gages consist of simple receptacles provided with a standard ring at the top. A layer of oil prevents evaporation. The hydrologist personally establishes the rain-gages in a pile of large stones in places known only to

himself (and which he must be able to find again).

Natural weirs can sometimes be used as river gaging sites on experimental catchments. Small, very light cableways are also used. In certain cases the beds of small water courses are stabilized with gabions. Stations on large water courses are simply equipped with a light cable, provided the section width is not too great.

The use of masonry or concrete in any quantity should never be envisaged. Even the footbridges composed of iron tubing of the type often used on experimental catchments in wetter regions are ruled out.

Regular gaging of very strong spates would require very costly installations. Thus floats for which correct use methods have been perfected are constantly employed. The major difficulty with this method is in following the variation of the cross section as the spate develops. As far as possible stable cross sections are to be used for measurements involving this method.

The very low density and the nomadic nature of the population is a handicap to the installation of a network. All sedentary inhabitants able to read are provided with an ordinary raingage. The isolated long-period storage gages are protected by a watchman if possible. In order to increase the number of measurements of rainfall intensity recorders the senior hydrologist takes one with him on his rounds. This instrument enables him to obtain valid data provided rainfall conditions are homogeneous. This recorder is often of the direct reading type, consisting of a simple gage with an aperture and a measuring tube. As rain constitutes one of the rare diversions as well as the main interest of the hydrologist it is certain that he will draw a first-rate graph.

One of the main problems in conducting research work on experimental catchments lies in the very small number of people engaged in these studies. This is because of the great difficulty in obtaining supplies.

Field visits involving long distances present problems both of measurement and of transportation. Whenever possible, the itinerary should cross the water courses where there are control sections having stable beds. A Liimimetric staff can be installed permanently at these points. If the water course is in spate when the hydrologist arrives he is generally

prevented from continuing on his way, but this is no handicap because his task then is to measure flow until the spate reaches a fairly advanced stage of subsidence. He next hurries to see if there has been any flow in the adjoining catchments and, losing no time, picks up the same water course further downstream to take further measurements there, continuing just as far as the dissipating area at the downstream limit where he checks the degree of flooding. Often, he will arrive too late. Nevertheless, in the desert, by arriving a short time after the flood, it is easy to reconstruct the line corresponding to maximum water level, for it is marked by small debris which does not disappear until at least a fortnight afterwards. The use of a maximum staff may facilitate this task, although none of these staffs give complete satisfaction. Flow can then be calculated from a topographical study of the bed and a flow formula, e.g., Manning's formula. The value of the coefficient is determined from regular measurements already taken on water courses of the same type.

For example, it has been found that in the case of even beds of 30 to 300 ft. width, with slopes ranging from 1.5 to 5% and a depth of water of 1 to 2 ft., the coefficient generally varies between 0.028 and 0.034. It may be as high as 0.065 if flow is very weak and the bed cluttered up with rocks and bushes. On the other hand, for the same slopes, the coefficient may drop to 0.02 if depth exceeds 3 ft. and if the bed is very even. (The itinerant hydrologist meanwhile looks for the marks of old spates.) Again it is not a *point* but a *line* of maximum level which is to be sought. This obviates all error and facilitates calculation of flow. Naturally, observation of the filling up of ponds, lakes and reservoirs provides valuable information.

Whenever possible a permanent measuring station or a simple recorder is installed, the latter being placed in a stony section if possible. It is checked by the itinerant hydrologist and often has to be protected by a watchman.

It is evident that the person responsible for the extensive study must possess the gift of observation and a critical mind as well as a good knowledge of the phenomena of the flow in the region.

Results obtained vary greatly depending on transportation facilities. If vehicles of the 'jeep'

type can be used, and this presupposes that itineraries will not cross flood plains on clayey soils, the hydrologist can travel much faster than spate flow. Under these circumstances he can form a good overall idea of flow during the rainy season. But if he is obliged to use camel transportation, his observation of flow is much more fragmentary.

Climate South of the Sahara presents a favorable element—storms from which flow is likely to result take place only during the period July–August–September, thus the time spent on the terrain by the hydrologist is limited to 3 or 3½ months and that spent by the assistant to 4 or 5 months. They are assigned to other research projects for the rest of the year and this considerably reduces costs.

The first research of this type was undertaken in 1957 in the Ennedi Massif, North-East of Tchad. No great hopes were founded on this trial in an area of very low annual rainfall (about 4 in.). (In these desert areas the expression 'mean annual rainfall' has a very restricted sense as annual totals are extremely variable.) In spite of a year of lower than average rainfall surprising results were obtained. It was possible to draw up an approximate rainfall map which brought out the low value of the rainfall gradient as a function of altitude.

Several direct measurements of flow were taken and numerous estimates of maximum flow were made *a posteriori*. A rough estimate was made of the annual volume of flow from several small water courses. Study of the experimental catchment showed the high percentage of runoff coming from storms of even less than ½ in., as well as the violence of spates on small catchments. The first values of evaporation using evapometric pans were also obtained for these areas. It was decided to continue research during the years following.

In 1958, again in Ennedi Massif, a second program of research was implemented. Heavy rainfall that year made possible the evaluation of spate flow of unusual frequency: return period of 5 to 20 years for a certain number of water courses and return period of 10 years for the experimental catchment. The following figures were obtained:

For catchments of 3 to 4 miles², 200 to 800 feet³ per second per mile² (depending on the catchment).

For catchments of 50 to 70 miles², 70 to 160 feet³ per second per mile².

For catchments of 150 to 230 miles², 35 to 90 feet³ per second per mile².

For catchments of 380 to 600 miles², 2.3 to 10 feet³ per second per mile².

In 1959 a third research program was undertaken in the Ennedi Massif. It comprised, in particular, the thorough study of a medium-sized water course. The effect of hydrographic degradation on spate flow was brought out clearly in this study and shown to be not more than 0.05 feet³ per second per mile² for a catchment of 3000 miles².

Research of the same nature was carried out simultaneously in the Air Massif in the North of Niger Republic. This massif receives an annual rainfall of 5 to 6 in. and the fact that vehicles could be used (though not without difficulty) and that the experimental catchment was located near a large water course made it possible to obtain much more complete results. It was possible to estimate the total volume of runoff coming from the massif. In a fairly wet year total runoff is 5.3×10^9 feet³ for an area of 10,500 miles².

Thus it was possible to estimate the figures for spates of fairly rare frequency (5 to 15 years) in the Air Massif:

For a catchment of 1 mile², 1500 feet³ per second per mile².

For a catchment of 40 to 60 miles², 90 to 450 feet³ per second per mile² depending on soil and slope.

For a catchment of 450 miles², 40 feet³ per

second per mile² (little hydrographic degradation).

Runoff from this massif is probably greater than from any other South of the Sahara. Solid load, evaporation and underflow were studied. Here again it was found that the pluviometric gradient is low.

In the same year (1959) a similar research program was carried out in Brakna and Tagant Massifs, in the South of Mauritania, on two experimental catchments, one of which had been under observation for two previous years. Once again a spate flow of fairly rare frequency and the annual volume of flow for various frequencies were calculated, providing fundamental data for the installation of reservoirs projected for the area.

Research of this nature cannot provide measurements or estimates of flow values of the same precision as in the humid regions. This is not a particularly grave handicap as the great interannual irregularity of rainfall would make it impossible to get as much out of the figures as might be expected. Furthermore, such research is scarcely to be envisaged in the case of total annual rainfalls of less than 2 to 3 in. for in such cases, at least one year out of two, the results obtained would be worthless.

A final point is that such research involves great hardships for those who undertake it. Summer is the most trying season of the year and the necessity of keeping on the move at all costs imposes veritable feats of endurance. However, up to the present, this method seems to be the only effective one for obtaining quantitative data on runoff in these areas.

Reviews

BUNDY, F. P., W. R. HIBBARD, JR., AND H. M. STRONG (Eds.) *Progress in Very High Pressure Research*, Proceedings of an International Conference held at Bolton Landing, Lake George, New York on June 13-14, 1960, John Wiley and Sons, New York, 314 pp., 1961, \$12.00.

The techniques of high pressure research are being profitably applied to a wide variety of scientific problems. Since there have recently been a number of significant advances in technique, this conference provided a timely opportunity for interdisciplinary discussions. The sponsors of the conference, Materials Central, Wright Air Development Division of the US Air Force, and the Research Laboratory of the General Electric Company, have made a valuable contribution in organizing these discussions and in making the proceedings available in book form.

The emphasis in most of the papers is on results rather than apparatus, although there is much useful information of an engineering and a procedural nature. Over half of the 27 technical papers are concerned with the general field of solid state physics, including the effects of pressure on reaction rates, optical and electrical properties of materials at high pressure, and equations of state for solids. The synthesis of high-pressure phases and phase equilibria studies, chiefly in metal systems, are given much space. In addition, there are valuable papers on temperature and pressure calibration and reviews of several aspects of high-pressure research. Extensive discussions by participants of the conference and lists of references are included.

Papers of particular interest to geophysicists include a discussion of melting and subsolidus transitions of a variety of metals in the pressure range up to 100 kb by H. M. Strong. Strong's data on iron and nickel provide a much improved estimate of the melting temperature of the Earth's core. G. C. Kennedy, G. J. Wasserburg, H. C. Head and R. C. Newton present a determination of the upper three-phase region in the system $\text{SiO}_2\text{-H}_2\text{O}$. Their data indicate that fluids with a widely variable $\text{SiO}_2/\text{H}_2\text{O}$ ratio could exist under physical conditions that are probably present in the lower portions of the Earth's crust during metamorphism and orogeny. S. P. Clark reviews the current state of phase equilibria studies of silicate systems at pressures over 10 kb and discusses their application to major geologic problems.

Very readable theoretical discussions of the effects of pressure on reaction rates and diffusion phenomena are presented by R. W. Keyes and by J. E. Hilliard and J. W. Cahn. Hilliard and Kahn include data on transformation rates in steels and other alloys obtained with the G. E. 'Belt' apparatus. Considerable additional information on diffu-

sion phenomena in metals and salts under pressure is given in papers by D. Lazarus and by C. K. Tamizuka. These results support the generalization that pressure decreases the rates of simple, diffusion-limited processes, but many of the data are quantitatively inconsistent with current theoretical models.

One of the principal problems in the design of very high pressure apparatus has been the development of solid pressure media with suitably low shear strength combined with high temperature stability and low electrical and thermal conductivity. H. T. Hall presents some basic information on this problem and also contributes a novel design for a hydraulic ram. J. C. Jamieson describes the use of single crystals of diamond for anvils and pressure vessels for high pressure X-ray studies. An extensive review of high-pressure research in the USSR is given by L. F. Vereshchagin. The Russian apparatus designs are similar to those developed in the US and Western Europe. Considerable work has evidently been done in the USSR in the high-pressure X-ray field and Vereshchagin presents data on the compressibilities of BN, graphite, Sr and Ba to 20 kb obtained in this way.

Measurement of pressure in many types of apparatus employing solid pressure media depends on calibration against subsolidus transitions in Bi, Tl, Cs and Ba. Estimates of the pressures of these fixed points vary by as much as 30% and accordingly data obtained above 25 kb in different laboratories are often not comparable. G. C. Kennedy and P. N. LaMori present new determinations of the Bi, Tl and Cs points which are much more accurate than previous values. They will be of great help in establishing a universally accepted pressure scale. F. P. Bundy describes the effect of pressure on the emf of a large number of thermocouples in the range up to 100°C and 100 kb. The effects he observed are significant; -8% for PtRh/Pt at 100 kb. Determination of these effects at higher temperatures will be most difficult, but is needed. Most high-pressure geochemical research is carried out in the range 500°C to 1800°C and significant corrections may need to be applied to existing data.

A general discussion of the behavior of matter at extreme pressure and temperature is given by B. J. Alder; various approximate theories are used to predict the behavior of hydrogen in the megabar range. C. A. Swenson describes the determination of an equation of state for sodium at 20 to 300°K at pressures up to 20 kb. Data on the elastic constants of sodium at room temperature and to 2,000 bars are given by W. B. Daniels. O. L. Anderson describes a method for obtaining accurate determinations of the equation of state

of solids in the range 1,000 to 5,000 bars and 50 to 350° K, with details on vitreous silica.

There is currently much interest in employing high-pressure techniques in metallurgical research. Apparently no major break-throughs have been made, but abundant changes in the equilibria and kinetics of phase-transformations in metals can be produced at high pressures. Papers by E. W. Goliber and K. H. McKee and by L. Kaufmann, A. Leyenaar, and J. S. Harvey describe some results in this field.

H. P. Bovenkirk describes the morphology of synthetic diamonds and relates the crystal forms, color, and surface features to the growth conditions. Most of the characteristics of the synthetic crystals are also found in natural diamonds. R. H. Wentorf has succeeded in crystallizing a cubic form of BN at pressures over 55 kb. The reaction requires a catalyst, and alkali and alkaline Earth metals and their nitrides have been found to be effective.

H. G. Drickhamer describes some remarkable apparatus for making optical studies at pressures up to 200 kb and temperatures to 500°C. The shifts of absorption-edge with pressure, and other optical effects, are given for a variety of elements and compounds. R. F. Harris, R. J. Vaisnys, H. Stromberg and G. Jura report resistance and thermal gap measurements to 400 kb with Bridgman anvil apparatus. Phosphorous and silver oxide were found to exhibit metallic conduction at 200 kb. These pressures are considerably higher than have been obtained by others with this type of apparatus. Effects of pressures up to 3000 bars on magnetic interactions in iron, nickel and Fe-Ni and Fe-Si alloys are presented by J. S. Kouvel and R. H. Wilson. Properties of semiconductors at high pressure are discussed by W. Paul. Some nuclear magnetic resonance measurements under pressure are given by G. B. Benedek.

The style of presentation and quality of these papers vary widely, as might be expected from the diversity and currently rapid rate of development of high-pressure research. Some authors have written about their specialties on a general level that will be intelligible to most readers; others have written primarily for investigators in their fields. There are a number of important papers and the aggregate amount of data and general information is very great. This book will be a most useful reference and the editors and publishers are to be commended for making it available so quickly.

F. R. Boyd

RAETHJEN, P., and O. HOEFELICH, *Zur Dynamik des Jet Stream*, Cram, De Gruyter and Co., Hamburg, 186 pp., 1961, DM 12.

This monograph consists of two parts. The first of these, by P. Raethjen, deals with disturbances of the balance of forces in nonstationary jet streams; its character is mainly theoretical. In the

second part, O. Hoeflich discusses Raethjen's concepts through synoptic analysis of a large body of case histories.

Raethjen's main trend of thought may be summarized as follows. Assume an initial zonal and geostrophic jet stream and then introduce a perturbation in the core which has the form of injection of wind speeds differing from those present in the initial equilibrium state. Because of the resulting geostrophic deviation, movement toward higher or lower pressure is initiated, and in the undamped case an inertial oscillation will develop downstream. With time, the pressure field becomes adapted to the new velocity distribution and then the whole jet stream takes on an oscillating character, with broad ridges and sharp troughs.

The perturbation is readily produced by rapid ascent (or descent) of air, with tendency toward conservation of momentum, through the strong vertical shear of the horizontal wind associated with jet streams. Such vertical displacement will occur most easily when, with onset of condensation, air can rise quickly in an environment where moist-adiabatic processes are unstable. Then large masses of air may enter the jet stream from below with velocities lower than initially present. These velocities therefore are subgeostrophic in the core and lead to motion toward lower pressure, i.e., to the left of the core looking downstream. With this, an anticyclonically curving current is initiated over and ahead of strong convective precipitation areas. This is the first branch of the inertial oscillation which then propagates downstream. Hoeflich's examples corroborate that such anticyclonic motion occurs, as has also been noted in other parts of the world from aerological data.

Raethjen's development is interesting and several of his deductions agree with certain important computations of other authors [Rossby, 1937; Kleinschmidt, 1951]. The treatment does not purport to yield an explanation of the jet stream as such, since an initial jet stream is postulated. Acceptance of the proposed mechanism is a matter for individual judgment; this reviewer has reservations. In the first place, one misses a quantitative treatment in which precise computations are offered to ascertain the actual importance of the proposed mechanism and to evaluate the possible effect of damping factors. The synoptic case histories are handled on an entirely qualitative descriptive basis. Second, examples can be cited for the atmosphere where a curving jet stream was generated at least a day prior to the onset of important precipitation. Finally, ocean currents such as the Gulf Stream have velocity distributions similar to that of the atmospheric jet stream; jet streams are readily generated in rotating laboratory experiments with water under a wide variety of experimental conditions [e.g., Riehl and Fuhs, 1957], with stable stratification.

In the reviewer's opinion a process has been described by Raethjen which, under proper circumstances, may contribute notably to the intensi-

fication of jet streams, but that it is not a necessary mechanism and that the basic reasons for the oscillatory aspect of jet streams still remain to be discovered.

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H. Riehl

PHILIP D. THOMPSON, *Numerical Weather Analysis and Prediction*, MacMillan Co., 170 pp., 1961, \$6.50.

This is the first book-length treatment on predicting the behavior of planetary atmospheres with electronic computers. It will be especially welcome since it is written by one of the recognized authorities in this field.

Separation from the parent field of dynamic meteorology is justified because the subject is one of increasing specialization. Furthermore, the author addresses not only meteorologists, but all geophysicists, mathematicians, and others who are interested in fluid behavior on planetary scales. Indeed, with the rapidly accumulating volume of data from the probings of inner and outer space, it will soon become feasible to solve complex non-linear problems in such fields as oceanography, the atmospheres of other planets, and possibly even stellar atmospheres. The author points out that already some applications have been made in the field of seismology.

To meet such a broad objective, the book has been written so that it is unnecessary for the student to wade through volumes of dynamic and synoptic meteorology in order to gain an understanding of the meteorologist's jargon. Only fundamental aspects have been presented which are likely to stand the test of time in a rapidly expanding field. The text has been stripped of all frills which are of special interest to meteorologists only, as well as of detailed discussions of physical problems as yet largely unsolved (e.g., the turbulent transfer of matter and energy). Those who want to pursue the matter further will find a carefully selected list of references at the end of each chapter.

The prospective reader should not take too literally the author's assertion in the preface that this is a 'primer.' This statement refers to the scope and not to the treatment of subject matter. One finds that the book is intended for the graduate student, and calls for 'certain prerequisites' in fluid dynamics, vector and ordinary calculus in-

cluding the solution of partial-differential equations, and finite-difference equations.

The only comparable texts, which attempt to bring the meteorologists' 15 years of experience in numerical analysis and prediction to the attention of other disciplines, are those of Eliassen and Kleinschmidt (*Handbuch der Physik*, v. 48, Geophysik II, Springer-Verlag, Berlin, 1957) and Phillips (*Advances in Computers*, v. 1, Academic Press, N. Y., 1960). These are necessarily somewhat briefer treatments, and consist of chapters from larger works.

Only highlights of the 15 chapters of Thompson's book will be mentioned here. The opening chapter is a review of the subject matter, intended for the non-specialist. It is an excellent example of the author's sense of scientific and historical perspective, his keen sense of humor, and clear and vivid style. Other chapters include a derivation of the basic hydrodynamical equations, a discussion of the solution of the primitive (i.e., unmodified) equations by finite-difference methods, the transformation of the primitive equations into the vorticity equation (which to some extent avoids problems arising from the quasi-balanced state of the atmosphere), methods for filtering out unwanted sound and gravity waves in order to maintain computational stability, and a long chapter on the practice of numerical forecasting in the United States, including methods of processing and analyzing raw data.

In Chapter 5 there is an excellent discussion of the use of linearized analytical solutions of the pure wave motions (sound, gravity, and Rossby waves) in determining the proper form for solving the finite-difference equations, and in Chapter 10 the wealth of material on energy transformations in the atmosphere is summarised.

Except for minor details, there is little adverse criticism that can be leveled at the unusually precise and elegant treatment of subject matter. The principal fault lies in the limited scope for a book-length treatment. Omitted are many significant contributions by meteorologists to atmospheric physics and applied mathematics, at least some of which appear to lie within the book's objectives.

Although there is considerable discussion of energy sources and sinks, no quantitative example is given of how heating and cooling may influence the atmospheric circulation. Perhaps this omission is because little is known about how to handle the complex physical processes involved in thermal energy transformations (see p. 48 and p. 164). Nevertheless, by adopting idealized non-linear or linear models containing simple forms of heating and friction, it is possible to throw much light on some important modes of atmospheric behavior. This has been done with profit by Phillips, Smagorinsky, Wiin-Nielsen, and others. In view of the fact that such influences are important for the long- and even short-period evolution of planetary atmospheres, such a discussion would be very useful.

The final chapter points up the enormous impact which these new techniques have already produced in the field of meteorology. The concluding remarks would lead one to believe that human weather observers, analysts, and even forecasters might soon join the ranks of the technologically unemployed, were it not for the final statement that only their routine functions will be taken over by machines. Scientists in other allied fields should take note and start now to build these techniques into their own experiments as their sources of data increase.

Philip F. Clapp

ADRIAN E. SCHEIDEGGER, *The Physics of Flow through Porous Media*, University of Toronto Press, 313 pp., revised 1960, \$15.50.

The revision of Scheidegger's book is probably the most comprehensive account of the literature on the flow of fluids through porous bodies that has been written to date. The text has been revised extensively. An unusual amount of material has been presented in about 300 pages. The choice is exceptionally good, and covers the whole field. Emphasis is placed on physical aspects and the subject matter is clearly presented. An extensive bibliography is included which contains most of the important papers.

In the first part of the book a good account is given of the geometrical properties of porous media and their measurement, including a brief outline of stress and deformation. The topics of fluid mechanics required for existing theories of flow through porous bodies follow. The parts of surface chemistry and capillarity necessary for an understanding of the subject matter are included. The hydrostatics of porous media is then discussed. Here is a very readable account of capillary condensation and the theory of sorption, as well as that of capillary pressure.

A complete development of Darcy's law is given in parts 4 and 5, including discussions of both isotropic and anisotropic porous media as well as compressible media. In part 5 the author applies Darcy's law to the problems of steady as well as unsteady flow and outlines the problem of gravity flow, with a free surface.

Part 6 contains a good account of capillary models and permeability relations are emphasized. The discussion of hydraulic-radius theories of porous flow that follows includes a good presentation of Kozeny's theory of fluid transmission. Emmerleben's ideas on the 'drag' theory of permeability, together with the later work of Iberall and Brinkman, are then discussed. Part 6 concludes with a development of the statistical theories of flow; the investigation of Boltzmann, about 1900, on the random packing of an assemblage of spheres, such as lead shot, would be helpful in this discussion.

Part 7 is devoted to a study of the general flow equations including flow at high velocities. A good

outline of the flow of gases, including effects of the mechanisms of solution, adsorption, and diffusion, is given. Reference is made to exchange-ion effects on the flow of liquid in clays.

The book is concluded with parts on displacement theory, and multiple-phase flow in porous media. Such topics as the flow of air-water mixture in soils, and the flow of oil, water and gas in porous media are treated. Muskat's work in this field is thoroughly reviewed. Thermal phenomena are discussed. Laminar flow of immiscible fluids, and the application of Darcy's law thereto are then presented in some detail. The author concludes with an account of displacement theory of miscible fluids, such as fresh water by sea water. A good summary of dispersion theory is included.

W. O. Smith

Manual of Photographic Interpretation, American Society of Photogrammetry, 868 pp., 1961, \$12.00 to members, \$15.00 to non-members.

The *Manual of Photographic Interpretation* is a book of 868 pages (6½ in. × 10 in.) and is more an encyclopedia of photographic interpretation than a manual. It is copyrighted and published by the American Society of Photogrammetry, under the editorship of Robert N. Colwell. Some ninety scientists in the field of photogrammetry, mostly interpreters or 'detectives' as called in the *Preface*, contributed to the chapters which cover the entire non-military spectrum of photo-interpretation to date. Illustrations, mostly in the form of stereopairs, are profuse throughout, and about a dozen full-page colored photos are used in certain chapters. The book's purpose is to help in the 'discovery, evaluation, and development of the earth's natural resources and in the intelligent planning for human occupancy of the earth's surface,' and certainly the progress in photogrammetry and photo interpretation in the last 25 years has made aerial photographs the most valuable single means toward this end. The manual is a monumental work.

Sixteen chapters constitute the book and represent the subjects treated as follows:

- Chapter 1—The Development of Photo Interpretation
- Chapter 2—Procurement of Aerial Photography
- Chapter 3—Fundamentals of Photo Interpretation
- Chapter 4—Photo Interpretation in Geology
- Chapter 5—Photo Interpretation of Soils
- Chapter 6—Photo Interpretation in Engineering
- Chapter 7—Photo Interpretation in Forestry
- Chapter 8—Photo Interpretation in Wildlife Management
- Chapter 9—Photo Interpretation in Range Management
- Chapter 10—Photo Interpretation in Hydrology and Watershed Management
- Chapter 11—Photo Interpretation in Agriculture

Chapter 12—Photo Interpretation in Urban Area Analysis

Chapter 13—Photo Interpretation in Archeology

Chapter 14—Photo Interpretation in Geography

Chapter 15—Special Forms of Photo Interpretation (Photomicrography, Electron microscopy, etc.)

Chapter 16—Education and Training in Photo Interpretation.

An extensive glossary of terms and an index are included.

A. J. Eardley

COMMITTEE FOR HYDROLOGIC RESEARCH T. N. O.,
Proceedings of the Technical Meetings 13 and 14, Central Organization for Applied Scientific Research in the Netherlands, The Hague, 199 pp., 1960.

This publication covers the 13th and 14th meetings of the Committee for Hydrologic Research held in 1957 and 1958 in the Netherlands.

The 13th meeting is entitled *Ground-water Levels and Ground-water Movement in the Dutch Sandy Soils*. It contains 11 papers by as many authors, all in Dutch. They all deal with specific Dutch hydrologic problems, so much so that even the references contain only articles written by Dutch investigators.

Nonetheless some interesting topics are worth mentioning. A. Volker reminds us that the idea of closing off the Zuider Zee and the Delta area in the provinces of South Holland and Zeeland by means of dikes to prevent salinization was proposed as early as 1667 by Hendrick Stevin. The Zuider Zee dike was built shortly before World War II and work on the Delta is now in progress.

In the second paper W. C. Visser gives a survey of the growth of soil moisture research and summarizes the mathematics describing drainage, de-watering, capillary rise and evaporation. Several graphs are presented showing that crop yields are higher when the pF of soil moisture is low and water easily available. He warns, however, against careless generalization of these findings.

G. P. Feltus describes the results of the use of an analog model to determine the effects of excessive pumping on an aquifer. The model consists of two plates representing the upper and lower boundaries of the aquifer with oil of high viscosity flowing between. Pumping, storage, and rainfall are quantitatively accounted for by suitable vessels and capillary tubes.

It is a well known fact that conversion of lakes into polders results in a lowering of the water table in adjacent higher land. C. H. de Jong shows how this decline can be prevented by the building of 'boundary lakes' (randmeren) around the polders.

The other articles deal with theory and practice of artificial recharge, inventory of ground-water, and surveys of permeabilities and storage capacities of the sandy soils in the Netherlands.

G. F. Makkink, in an addition to R. Wind's

paper on net precipitation (which appears to amount to 35 to 60% of the total yearly precipitation), makes the interesting statement that in Germany little value is attached to Penman's method of calculating net precipitation. Dozens of lysimeters are being built in Germany to evaluate the natural recharge of groundwater.

The 14th meeting is entitled *Water in Unsaturated Soil*. The five papers dealing with this subject are of a much more general character and were, therefore, published in English. This is fortunate because they contain valuable contributions to a topic that has the increasing interest of many soil physicists in this country.

A brief introduction by F. Hellings is followed by a general survey of the problems of soil moisture. The authors, P. K. Peirlkamp and P. Boekel, discuss several well known methods of determining pF values. For low values ($pF < 2$) they use a simple sand tank with an adjustable water table.

The third article by T. C. Haans, *Available Moisture in Soils of the Netherlands*, presents profile sketches of texture, humus content and water-air-solid percentages of different types of sandy soils. The term 'available moisture' is defined as the difference between moisture content at field capacity ($pF = 2.2$) and at wilting point ($pF = 4.2$) in a one meter profile. The discussion following the text suggests that several participants did not agree with this definition. Haans points out that 'not all of the so-called available moisture is equally available for (sic) plants. It is generally accepted that the intake of moisture becomes more difficult with increasing moisture tension.' The reviewer has never seen a much debated question settled so categorically.

The last two articles by J. Wesseling and F. P. Wind deal with the phenomena of unsaturated flow. They are both excellent reviews of the present state of knowledge about this difficult subject.

Wesseling's paper, *Principles of the Unsaturated Flow and Their Application to the Penetration of Moisture into the Soil*, discusses the infiltration phenomenon. It is by far the best paper in the collection. In a clear concise presentation, the laws governing flow in unsaturated soils are discussed and experiments on, and theories of, infiltration are presented.

Wind's paper, *Capillary Rise and Some Applications of the Theory of Moisture Movement in Unsaturated Soils*, discusses capillary rise under stationary conditions. The introduction of the term 'opdrachtigheid' (literally 'upbringing capacity') for the capacity of a soil to deliver a large quantity of water to a crop is interesting. Wind explains the phenomena by high capillary conductivity. The differences in capillary conductivity also explain why sandy soils have more weed problems than clayey soils.

The articles of both meetings, in groups and individually, are followed by what seem to be verbatim reports of the discussions. Some of the

papers could have benefited from an English editor. There are a few amusing 'Dutch-isms,' but by and large the authors are to be complimented

for a successful effort to make Dutch knowledge available to an international audience.

T. E. A. van Hylckama

Recent Publications of Interest to Geophysicists

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Translations of Soviet Abstracts

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Abstracts of interest to AGU members are shown below. This list is taken from *English Abstracts* No. 6 (July), 1961, Series I and Series VI. In each entry, the series and page number are shown.

The following list appears in this issue of *Transactions* on a trial basis. If the list proves helpful to you, please let us know. If response is not sufficient, the list will be dropped after this issue.

English Abstracts is distributed by the US Department of Commerce, Office of Technical Service, Washington 25, D. C. Price of each series is \$9.00 for six bimonthly issues.

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- DROBYSHEV, F. V., Measuring stereoscope; *Izvestiya Vysshikh Uchebnykh Zavedeniy. Geodeziya i Aerofotos' Yemka*, ser. VI, p. 107.
- DROBYSHEV, F. V., A measuring stereoscope; *Byulleten' Izobreteniy*, ser. VI, p. 110.
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- New orbital elements relative to seventeen minor planets; *Tien Wen Hsueh Pao, Acta Astronomica Sinica*, ser. I, p. 545.
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Notes and Personalia

Notes

- GEOLOGICAL SURVEY REPORT ON YUKON RIVER—The U. S. Geological Survey has released for public inspection a report entitled 'Preliminary Geology along the Lower Yukon River, Alaska,' by J. M. Hoare. Copies are available for consultation in Geological Survey libraries.
- NEW IONOSPHERIC SOUNDING STATION IN BRAZIL—An ionospheric sounding station has recently been established near Natal, Brazil, at a point just

under the magnetic equator. It is located at Guarapes, approximately 13 miles southwest of Natal, and the available space and resources on the selected site allow for its growth into an experimental geophysical station.

- GRANTS-IN-AID FOR RESEARCH IN PETROLEUM GEOLOGY—The American Association of Petroleum Geologists will award grants for research in which emphasis is placed on the development of princi-

ples as contrasted to data-gathering or problem-solving with known techniques. Applications must be submitted before January 1, 1962, to AAPG, Box 979, Tulsa 1, Okla.

• **INFORMATION PROCESSING CONGRESS, 1962**—The American Federation of Information Processing Societies announces the Second International Congress on Information Processing to be held in Munich, Germany, August 27–September 1, 1962. The meeting will feature equipment exhibitions as well as technical sessions. For further information get in touch with the American Federation of Information Processing Societies, 142 the Great Road, Bedford, Massachusetts.

• **SCRIPPS EXPEDITION IN THE BERING SEA AND GULF OF ALASKA**—Research Vessels *Stranger* and *Hugh M. Smith* of the Scripps Institution of Oceanography spent the period from July 21 to September 17, 1961, on 'Leapfrog Expedition,' which was designed primarily to study seismic refraction and heat-flow measurements. The particular area near the coast of Alaska was chosen because it provides an almost ideal setting for detailed geophysical measurements in the transition zone between continent and ocean. The cruise was under the direction of George G. Shor, Jr.

• **FLIGHT OF LIGHT PHOTOGRAPHED**—By an image-sweeping technique using a series of mirrors placed at successively greater distances from the source of the flash, Space Technology Laboratories of Los Angeles took pictures of light in flight by means of its electronic Image Converter Camera. The technique may be of future use in measuring distances on Earth and in space, or in providing a new means of measuring light speed.

• **NEW MEASUREMENTS FOR MOUNT EREBUS**—Previous figures for the elevation of Mount Erebus in Antarctica have been replaced by measurements made with theodolite and Tellurometer during the 1960–1961 austral summer by the Geological Survey of the Interior Department. The new figure is 12,280 feet, or 3,743 meters.

• **IMPROVED OIL RECOVERY PROCESS**—The Pure Oil Company has developed a more effective process for the recovery of crude oil from any type of underground petroleum reservoir by use of solvents that are soluble in both oil and water. The process is effective at any pressure and with a wide range of crude oils.

• **GROUND WATER IN ARIZONA**—Artesian pressure in the San Simon Basin in Arizona has declined 80 feet in 45 years according to reports of the US Geological Survey. Ground-water reservoirs have been increasingly used in this area for irrigation purposes.

• **NEW RESEARCH SHIP FOR WOODS HOLE OCEANOGRAPHIC INSTITUTION**—A 210-foot research vessel, *Atlantis II*, is being built for the Woods Hole Oceanographic Institution with the aid of a grant from the National Science Foundation. It will be the first completely new ship built for Woods Hole in thirty years. *Atlantis II*, to be completed by mid-1963, will have an underwater observation

chamber and four laboratories, including one below decks at the center of least motion for gravity measurements.

• **TEXAS ATLAS TO BE PUBLISHED**—A geologic atlas of Texas will be compiled by the University of Texas Bureau of Economic Geology as a new research project supported in part by contributions from oil companies and professional geological societies in the state. The new map project will involve compilation of 37 maps on a scale of 4 miles to the inch. Each sheet will be 22 by 38 inches and will encompass an area of one degree of latitude by two degrees of longitude. The 37 sheets will be published individually. The Tyler and Palestine areas in East Texas are the first scheduled for completion. Dr. Virgil E. Barnes, Bureau Research Scientist and University geology Professor, will direct the map project.

• **FIRST ISOTOPE-POWERED WEATHER STATION**—The world's first isotope-powered, automatic weather station has been installed in the Canadian Arctic by the Department of Transport of Canada, the US Atomic Energy Commission and the US Weather Bureau. The weather station, capable of functioning unattended for two years, is in the vicinity of Norwegian Bay, about midway between Joint Arctic Weather Stations at Eureka and Resolute.

Wind direction and speed, temperature, and barometric pressure readings will be fed into a data processing system and every three hours will go directly, by radio transmitter, to the receiving stations at Resolute and Alert.

The unique power source, located in the lower chamber of the container, consists of a strontium-90 heat generator and thermocouples, batteries, and a converter; it uses a safe, insoluble chemical form of the isotope strontium-90 securely locked in a corrosion-resistant capsule and shielded by three quarters of a ton of lead. The excess heat from the strontium-90 is used to maintain an interior operating temperature of approximately 70°F. This element produces thermoenergy to charge a nickel-cadmium storage battery system, which in turn activates the radio transmitter. The isotope of strontium-90 has a relatively long half-life and is capable of producing usable power for over ten years.

• **GEOLOGICAL SURVEY GETS NEW ELEVATION METERS**—Two new mobile elevation meters, designed to determine automatically relative land elevations, are now being used by the Geological Survey in its topographic mapping operations. The elevation meters are electro-mechanical devices built into specially modified motor vehicles and used to determine elevations of control points for producing topographic maps from aerial photographs. The instruments are expected to speed up field mapping procedures and result in more economical operations where roads are available for their use.

• **COOPERATIVE RESEARCH IN MEXICO**—The Department of Geology and Bureau of Economic Geol-

ogy of the University of Texas and the Instituto de Geologia de La Universidad Nacional Autonoma de Mexico have signed a cooperative agreement for geologic research in Mexico. University of Texas graduate students will undertake research work in Mexico. The Instituto de Geologia will designate problem areas, cooperate in supervision, furnish field assistance, materials and supplies, help defray field expenses, and provide for publication in Spanish. The Instituto will also recommend Mexican candidates for graduate study at the University of Texas and assist in financing their graduate studies. The Department of Geology and Bureau of Economic Geology will direct the geologic research in Mexico, supervise the field work and provide financial assistance for Mexican graduate students.

• **CLOSING DATE FOR NSF GRANTS**—The National Science Foundation announces that March 1, 1962, is the next closing date for receipt of proposals in the Graduate Laboratory Development Program. This program requires at least 50% participation by the institution with funds derived from non-Federal government sources.

The grants are to aid institutions of higher education in modernizing, renovating, or expanding graduate-level basic research laboratories used by staff members and graduate students. Only those departments having an on-going graduate training program leading to the doctoral degree in science at the time of proposal submission are eligible at present.

Proposals and requests for additional information should be addressed to the Office of Institutional Programs, National Science Foundation, Washington 25, D. C.

• **HIGH PRESSURE STUDIES AT LEHIGH UNIVERSITY**—Lehigh University has received a \$20,000 grant from the National Science Foundation for research on 'Synthesis and Stability of the Mineral Apatite.' The research program will continue for two years under the direction of Dale R. Simpson.

Water vapor pressures as high as 60,000 psi and temperatures to 900°C will be used to determine the conditions necessary for synthesizing apatite. Also, maximum pressures and temperatures at which this mineral can exist will be investigated.

• **WEST INDIES VOLCANOES STUDIED**—A field study on volcanoes in the West Indies has been undertaken by the Department of Geology and Mineralogy, University of Oxford, and the Seismic Research Unit of the University College of the West Indies. A five-year detailed petrological study of the volcanic rocks of the British Leeward and Windward Islands is planned, under the supervision of L. R. Wager and G. M. Brown at the University of Oxford and G. R. Robson and P. H. A. Martin-Kaye in the West Indies. The work will include mapping of the structure of the volcanoes and recognition and classification of the phases of recent volcanic activity.

• **DEGREES OFFERED IN SCIENTIFIC HYDROLOGY**—The nation's first formal education program in scientific hydrology is being offered this year by the University of Arizona. John W. Harshbarger, head of the University's Department of Geology and widely recognized leader in the field of water studies, termed the new program 'a natural outgrowth of demand created by students who wish to become scientific hydrologists.' Twenty students representing ten countries are presently taking hydrology courses here. The first BS and PhD degrees in Scientific Hydrology may go to two of these students next year.

The University of Arizona program will offer six entirely new scientific hydrology courses which will serve as the core of the graduate study program—field hydrology, hydrologic systems, dynamics of flow systems of the Earth, continental hydrology, analog model analysis of hydrologic systems, and mathematical statistics in hydrology. A brochure describing the new program is available from the Department of Geology, College of Mines, the University of Arizona, Tucson.

• **SPACE AWARD ESTABLISHED**—The General Thomas D. White Space Award has been established by the National Geographic Society to "encourage and ensure further conquests of space." The award will be presented annually 'to that military member or civil service employee of the Air Force who has made the most outstanding contribution to the Nation's progress in aerospace.'

• **NEW GEOPHYSICAL JOURNAL**—The Mexican Geophysical Union, established in 1960, is publishing a scientific quarterly *Geofísica Internacional*. The Journal is published in Spanish and one of the four following languages: English, French, German, or Russian. Subscription price for 1961 is \$6.00. Address inquiries to Union Geofísica Mexicana, Torre de Ciencias 3er. Piso, Ciudad Universitaria, Mexico 20, D. F., Mexico.

• **INTERNATIONAL CONFERENCE ON PALYNOLOGY**—A conference which will bring together scholars in all phases of palynological research will be held April 23-27, 1962, at the University of Arizona in Tucson. Among symposia and round-table conferences planned are 'The Cretaceous-Tertiary Boundary, and 'Pleistocene.' For more information, write to International Conference on Palynology, Geochronology Laboratories, University of Arizona, Tucson.

• **WEATHER BUREAU HURRICANE RADAR NETWORK COMPLETE**—The Weather Bureau now has radar warning sentinels scanning the coastal waters from Southern Texas to Maine. The commissioning of long-range storm-detection weather radar at Atlantic City, New Jersey, this fall was the final link in the network of stations in the hurricane belt. The new equipment has already been used during the past hurricane season. These radar sets, called WSR-57, are specially designed for weather surveillance. The radar, costing about \$100,000.00, has a peak power output of 500,000 watts. It will detect any well-developed hurricane whose eye is within 200 miles of the coasts and weaker storms at somewhat lesser distances. The 12-foot

dish-type antenna is mounted on a high vantage point and enclosed in an 18-foot Fiberglas reinforced plastic sphere for all-weather operation.

● **XTH PACIFIC SCIENCE CONGRESS**—This Congress, held in the friendly atmosphere of the University of Hawaii in Honolulu August 21 to September 6, was attended by more than 2700 scientists, technologists, and their guests. Although the full spectrum of science was covered, special emphasis was placed on problems of and applications to the Pacific Basin, and most of the participants were from countries in or bordering on the Pacific. Delegates and representatives from more than 60 countries attended. There was a strong program bearing on geophysics—meteorology, vulcanism, the Earth's crust, morphology, and oceanography. Oceanographic research vessels from the United States and the USSR were in the harbor for inspection.

Most of the formal sessions were held before 1 p.m. each day; field trips were held each afternoon, and receptions and other social affairs frequently filled the late afternoon and evening hours. In addition, there were several post-Congress field trips to the other islands of the Hawaiian archipelago, ranging from four to ten days.

Many members of the AGU presented papers, and took part in the planning and presenting of the program. Many more were in attendance.

Plans have been made to publish some of the symposia in AGU's Geophysical Monograph Series; others will be published in the IUGG Monograph Series.

Harold J. Coolidge of the Pacific Science Board served as Secretary General of the Congress. Gordon A. Macdonald was in charge of the arrangement of the program in geophysics, under the general direction of Lloyd V. Berkner.

● **US ANTARCTIC RESEARCH PROGRAM FOR 1962**—With the start of the southern hemisphere summer in October, scientists from more than 25 universities, research institutions, and government agencies will undertake research projects in the Antarctic area. The National Science Foundation, which supports and coordinates the US Antarctic Research Program, has awarded grants and contracts totaling about \$5,500,000.

Projects being directed by AGU members include Operations Upkeep, the replacement of South American Earth-strain stations at Nana, Peru and Santiago, Chile, by Hugo Benioff of the California Institute of Technology; continuation studies of VLF phenomena in the Antarctic by R. A. Helliwell of Stanford University; conjugate point measurements of high altitude radiation effects in the geomagnetic field by Robert R. Brown of the University of California; design of radio antenna complex for floating Antarctic research station by Fred W. Brown of the Central Radio Propagation Laboratory of the National Bureau of Standards; the distribution of rubidium, strontium, cesium, and barium in oceanic vertical profiles with special emphasis on the Antarctic by

Karl K. Turekian of Yale University; a limnological and geochemical investigation of Lakes Bonney and Vanda in the Antarctic by Kenneth B. Armitage and Ernest E. Angino of the University of Kansas; Ross Ice Shelf studies by James H. Zumberge of the University of Michigan; support of airlifted geophysical program in Antarctica by Edward C. Thiel of the University of Minnesota; bedrock geology of the Sentinel Mountain Chain and northwestern Marie Byrd Land in West Antarctica by J. Campbell Craddock of the University of Minnesota; work in Antarctica 1961-1962 season by James A. Bender of the US Army Cold Regions Research and Engineering Laboratory; a study of pedologic processes in Antarctica by J. C. F. Tedrow of Rutgers University; seismic reflection measurements in high southern latitudes and equipping a research vessel for geological, geophysical, and oceanographic research in Antarctic waters by Maurice Ewing of Columbia University; radioisotope studies in the oceans with special emphasis on the Antarctic by W. S. Broecker of Columbia University; an institute of polar studies and traverse glaciology of Antarctic firm by Richard P. Goldthwait of the Ohio State University Research Foundation; continuation of investigations of time variations of the primary cosmic radiation near the south geomagnetic pole by Martin A. Pomerantsev of the Bartol Research Foundation; the calcium carbonate saturation level of the ocean from latitudes of North America to Antarctica by Donald W. Hood of the Texas A and M Research Foundation; surface and deep current measurements in the Drake Passage by Dale F. Leipper and Luis Capurro of the Texas A and M Research Foundation; the auroral heights measurement program and the continuation of aurora and airglow research in Antarctica by Norman J. Oliver, Jr., of the Arctic Institute of North America; General support of the Tenth Pacific Science Congress by Harold J. Coolidge of the National Academy of Sciences; US magnetic observatories, 1961-1962, Antarctic, and USARP magnetic field surveys in Antarctica, 1961-1962, and Antarctic seismological observatories by H. Arnold Karo of the US Coast and Geodetic Survey; a program for Antarctic mapping operations, fiscal year 1962, by Thomas B. Nolan of the US Department of Interior, Geological Survey; systematic geologic mapping and related studies in the Horlick Mountains, West Antarctica, by Charles A. Anderson of the US Department of Interior, Geological Survey; providing standard geographic nomenclature in Antarctica for United States use by Meredith F. Burrill of the US Department of Interior, Office of Geography; Antarctic meteorological research program, atmospheric-oceanic-glaciologic interaction in an Antarctic interdisciplinary research program, and international Antarctic analysis center, United States participation by F. W. Reichelderfer of the US Weather Bureau; Continuation of the Geophysical and Polar Research Center at the University of Wis-

consin and gravimetric connections and magnetic observations between key points in Antarctica by George P. Woollard of the University of Wisconsin; continued study of patterned ground in the Antarctic by Robert F. Black of the University of Wisconsin.

• **GRADUATE FELLOWSHIP DEADLINE NEAR**—The National Science Foundation has announced the closing date for receipt of applications for graduate fellowships as January 5, 1962. Fellowships will be awarded for study in mathematics, physics, en-

gineering, anthropology, geography, and philosophy of science. They are open to college seniors and graduate students. All applicants must be citizens of the US and will be judged solely on the basis of ability. The annual stipends for graduate fellows are \$1800 for the first year, \$2000 for the second year, and \$2200 for the last year. Write to the Fellowship Office, National Academy of Sciences—National Research Council, 2101 Constitution Avenue, N.W. Washington 25, D. C.

Personalia

• **GEORGE BAKER**, Principal Research Officer on Minerographic Investigations of the Commonwealth Scientific and Industrial Research Organization in Victoria, Australia, has been named the first recipient of the Research Medal of the Royal Society of Victoria. The medal was established to commemorate the Centenary of the Royal Society of Victoria which took place last year. Dr. Baker's outstanding work in tektites has won him international recognition.

• **CHARLES L. BRETSCHNEIDER** is now in charge of the Washington office of National Engineering Science Company. He is the former Chief of the Oceanographic Branch in the Research Division of the Beach Erosion Board of the Corps of Engineers.

• **P. EDWARD BYERLY**, formerly with the US Geological Survey, Washington, D. C., has joined the staff of the La Habra Laboratory, California Research Corporation, San Francisco, as a research geophysicist.

• **PERRY BYERLY** of the University of California in Berkeley was one of the US representatives at a UNESCO meeting on seismology in Japan.

• **PRESTON CLOUD, JR.**, of the US Geological Survey, has been appointed Chairman of the Department of Geology at the University of Minnesota. He succeeds George A. Thiel who is retiring.

• **ALBERT P. CRARY**, Chief Scientist of the Office of Antarctic Programs for the National Science Foundation, has been given an Incentive Award check for \$4700 by the Office of Aerospace Research of the Air Force.

• **MILTON B. DOBRIN**, Chief Geophysicist for United Geophysical Corporation, Pasadena, has been elected First Vice-President of the Society of Exploration Geophysicists.

• **JAMES L. DYSON**, Head of the Geology Department of Lafayette College, has been elected President of the Pennsylvania Academy of Science for the year 1961-62.

• **RHODES W. FAIRBRIDGE**, Professor of Geology at Columbia University, will be on sabbatical leave until September 1962. He is currently leading an expedition in northern Sudan, and will spend the

spring and summer months as Visiting Professor at the Sorbonne, Paris.

• **LAWRENCE Y. FAUST**, Geophysical Supervisor for Amerada Petroleum Corporation in Tulsa, has been elected President of the Society of Exploration Geophysicists. New officers were installed at the Society's November meeting.

• **BERNARD FRANK**, Professor of Watershed Management at Colorado State University, and Robert E. Dils, Leader of the Cooperative Watershed Management Unit at Colorado State University, have received a two-year grant from the Conservation Foundation of New York to prepare a textbook on watershed management.

• **HERBERT FRIEDMAN** has been appointed part-time Professor of Physics at the University of Maryland. He is currently Superintendent of the Astrophysics Division, Naval Research Laboratory, Washington, D. C.

• **ALBERT FRZ**, Chief of the Tennessee Valley Authority Hydraulic Data Branch, has retired after 28 years with TVA.

• **JOSEPH L. GILLSON**, retired Chief Geologist for the DuPont Company, has been named William Otis Crosby lecturer in geology at Massachusetts Institute of Technology for the academic year 1961-62.

• **JAMES GILLULY**, Staff Geologist of the US Geological Survey, has been elected a Foreign Member of the Geological Society of London.

• **ILMO HELA**, formerly Director of the Institute of Marine Research in Finland, has begun his new duties as Chief Scientist in charge of the program of research on the effects of radioactivity in the sea, conducted in Monaco under an agreement between the International Atomic Energy Agency, the Government of the Principality and the Institute of Oceanography.

• **GEORGE W. HOUSNER**, Professor of Civil Engineering and Applied Mechanics at the University of California in Berkeley, was a US representative to a meeting of the UNESCO mission in Japan during July where recommendations were drafted for protection against earthquake hazards in Southeastern Asia.

- M. KING HUBBERT, Consultant in general geology to the Shell Development Company, Houston, Texas, has been named Visiting Professor of Geology and Geophysics at Stanford for the winter quarters of the academic years 1961-62 and 1962-63.
- JOSEPH KAPLAN of the University of California at Los Angeles, and Chairman of the US National Committee for the International Geophysical Year, has been elected to the Council for the Advancement of Science Writing.
- DON KIRKHAM was one of ten panelists on the use of radioisotopes in agriculture at a recent meeting of the International Atomic Energy Agency at Vienna, Austria. He spent the fall months in Egypt.
- P. E. LAMOREAUX, former Chief, Ground Water Branch, US Geological Survey, was appointed to the position of State Geologist and Oil and Gas Supervisor in Alabama.
- FINLEY LAVERTY, Assistant Chief Engineer of the Los Angeles County Flood Control District, has been chosen to receive the American Society of Civil Engineers Professional Recognition Award.
- DANIEL LINEHAN was in southeast Asia during June and July where he was a US representative on a UNESCO mission which studied earthquake engineering and offered recommendations to the Asian nations on how to protect their people against earthquakes.
- JAMES P. LODGE has joined the staff of the University Corporation for Atmospheric Research in Boulder. He was formerly at the Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio.
- SYVERRE PETERSEN, Professor of Meteorology and Chairman of the Department at the University of Chicago, has been named Chairman of the University's newly created Department of Geophysical Sciences.
- CHARLES PIERCE has retired from his position of Deputy Director of the US Coast and Geodetic Survey. He had been with the Survey since 1923.
- FRANK PRESS, Professor of Geophysics at the California Institute of Technology, has been named California scientist of the year by the California Museum of Science and Industry Foundation. The annual award carries a prize of \$5000.
- K. R. RAMANATHAN, Director of the Physical Research Laboratory, Ahmedabad, India, and Past President of the International Union of Geodesy and Geophysics, has been awarded the International Meteorological Organization Prize for his outstanding work in meteorology and international cooperation.
- ROGER R. REVELLE, Dean of the School of Science and Engineering of the University of California at San Diego and Director of the Scripps Institution of Oceanography, is on leave of absence from these duties and is serving as Science Advisor to the Secretary of the Interior with headquarters in Washington, D. C.
- WALTER ORR ROBERTS, Director of the University Corporation for Atmospheric Research at Boulder, was keynote speaker at the 31st Annual International Meeting of the Society of Exploration Geophysicists in Denver during November. Theme of the meeting was 'Exploration in a Changing World.'
- PAUL A. SCHERRER, Former Executive Officer of the Carnegie Institution of Washington, has been appointed Special Consultant to the Director of the National Science Foundation.
- WALDO E. SMITH, Executive Secretary of the American Geophysical Union, has been elected a Director of the American Society of Civil Engineers.
- A. K. SNEELGROVE, Head of the Department of Geology and Geological Engineering at the Michigan College of Mining and Technology, has been appointed Fulbright Lecturer for 1961-62 at the University of Sind, Nyderabad, West Pakistan; he will lecture on economic geology.
- FRED N. SPIESS has been appointed to a one-year term as Acting Director of Scripps Institution of Oceanography of the University of California, replacing Roger Revelle, who is on leave of absence serving as Science Advisor to the Secretary of the Interior.
- HARLAN T. STETSON has been awarded the John A. Fleming Medal of the American Institute of Geonomy and Natural Resources, Inc. The medal is given for 'outstanding accomplishments for science in the art of living.'
- LORENZ G. STRAUB and ALVIN G. ANDERSON have received the American Society of Civil Engineers Norman Medal for their paper 'Self-Aerated Flow in Open Channels.'
- CHARLES V. THEIS, who has been with the Water Resources Division of the US Geological Survey for more than 30 years, is now Adjunct Professor of Geology at Columbia University.
- JAMES C. TISON, JR., has been picked by President Kennedy to be Deputy Director of the Coast and Geodetic Survey, with the rank of Rear Admiral. Tison has been with the Survey since 1929.
- JAMES A. VAN ALLEN, Head of the Department of Physics and Astronomy at the University of Iowa, has been named an Elliott Cresson Medalist of the Franklin Institute.
- C. H. M. VAN BAVEL was one of ten panelists on the use of radioisotopes in agriculture at a recent meeting of the International Atomic Energy Agency at Vienna, Austria.
- FRANK L. WEAVER, who retired in May after 16 years as Chief of the Division of River Basins of the Federal Power Commission is now a consultant in river basin and hydroelectric engineering. He received a Distinguished Service Award from the FPC when he retired, in recognition of his outstanding work in river basin development.
- JOSEPH V. B. WELLS, Delaware River Master and Assistant Chief of the Water Resources Division of the US Geological Survey, received the Distinguished Service Award of the Department

of the Interior. The citation of the award recognized his 'more than 30 years of outstanding service in the fields of hydraulic engineering and hydrology with the Survey.'

• **BASIL W. WILSON**, formerly Professor of Engineering oceanography at Texas Agricultural and Mechanical College, is now a member of the Senior Staff at the National Engineering Science Company in Pasadena, Calif.

• **RALPH LEROY BELKNAP**, Professor of Geology at the University of Michigan, Ann Arbor, died December 17, 1960, at the age of 60. Born at St. Clair, Michigan, he received a BS in 1923 and an MA in 1924 from the University of Michigan. Also, he held the Doctor of Science degree from both the University of Michigan (1929) and the University of Chicago (1941). His entire career was spent teaching geology and meteorology at his alma mater, beginning first as an instructor in 1923. On several occasions he served as geologist and meteorologist for Greenland expeditions. He had been a member of AGU since 1942.

• **PERCY WILLIAMS BRIDGMAN**, Nobel Prize Winner and leading world authority on very high pressure, died August 20, 1961, at the age of 79. He was born April 21, 1882, at Cambridge, Massachusetts. His baccalaureate and master's degrees were secured from Harvard University, and he completed his PhD in physics at the same university in 1908. He was awarded honorary degrees from Harvard, Stevens Institute, Brooklyn Polytechnic Institute, and Princeton, Yale, and Paris Universities. In 1954 he retired from the Higgins professorship at Harvard after serving on the faculty in various capacities from 1910. His invention of a high-pressure apparatus and his discoveries with it in the field of high-pressure physics secured him the Nobel Prize in Physics in 1946. Previously he had received the Rumford, Cresson, and Roseboom medals, the Comstock Prize, and the Research Corporation, New York, award. He was a member of the National Academy of Sciences and had been a member of AGU since 1931.

• **FRANK CECIL FARNHAM**, Consulting Geophysicist of Grove City, Pennsylvania, died on February 8, 1961, at the age of 60. He was born in Archer, Nebraska, took his baccalaureate degree from Nebraska Wesleyan University in 1924, and his MS from New York University in 1926. He began teaching at the Missouri School of Mines in 1926, becoming Assistant Professor in 1928 and continuing until 1938. From 1938 to 1952, he was with the US Geological Survey. Upon his retirement he had consulting work. He had been a member of AGU since 1939.

• **ROBERT PARKER IRELAND**, analyst with Central Intelligence Agency, died August 1, 1961, at the age of 52. His birthplace was Spokane, Washington. After securing his baccalaureate degree from Northwestern University in 1934 he served with the Corps of Engineers as geologist, engineer, and military intelligence specialist until 1952. Service

with the US Forest Service preceded his last post with Central Intelligence. He was a member of the American Association for the Advancement of Science and had been a member of AGU since 1947.

• **PATRICK JOSEPH LUCEY**, professional engineer, died August 18, 1960, at the age of 71. He was born in Walworth County, South Dakota, and was a student in mechanical engineering at the Lewis Institute in Chicago from 1911 to 1913. He has held important positions with many organizations including Standard Electric Products Company in Philadelphia and the Lucey Equipment and Supply Company. He had been a member of AGU since 1959.

• **ERNESTO PICHLER**, Civil Engineer with the Instituto de Pesquisas Tecnológicas, Sao Paulo, died November 27, 1959, during a field trip in Brazil. He was born in Innsbruck, Austria, and received a degree in civil engineering from the Escola Politécnica de Sao Paulo in 1938. He had done work in economic geology, soil mechanics, and similar areas related to geophysics since joining the Instituto de Pesquisas Tecnológicas in 1936. He had been a member of AGU since 1953.

• **HOWARD PERCY ROBERTSON**, Professor of Mathematical Physics at California Institute of Technology, Foreign Secretary of the National Academy of Sciences, and Scientific Advisor to President Kennedy and the Department of Defense, was killed in an automobile accident on August 26, 1961, at the age of 59. Born in Hoquiam, Washington, he received a baccalaureate degree from the University of Washington in 1922, and a MS in 1923. In 1925 he received a PhD from California Institute of Technology. He was a professor of mathematical physics at Princeton University from 1925 to 1938, teaching also at California Institute of Technology, 1927 to 1929. He became Professor of Mathematical Physics at Caltech in 1938, the position which he held at the time of his death. He served as Director of Research for the Weapons Systems Evaluation group in the Office of the Secretary of Defense, 1950-1952, and as Science Advisor to the Supreme Allied Commander in Europe, 1954-1956. In 1946 he was awarded the Medal of Merit. He was a member of the National Academy of Sciences, becoming Foreign Secretary of that body in 1958, in which capacity he served on the Council of AGU for the past year.

• **THOMAS GORDON THOMPSON**, Professor Emeritus of Oceanography at the University of Washington in Seattle, died August 10, 1961, at the age of 72. He was born in Rosebank, New York, November 28, 1888. He received his baccalaureate degree from Clark University in 1914, and his PhD in 1918 from the University of Washington. Except for military leave of absence during the war years, he devoted his entire career to work at the University of Washington. He was an Instructor in 1919, Assistant and Associate Professor from 1920 to 1930, Director of Oceanographic Laboratories

from 1930 to 1951, and Professor from 1951 to 1959, when he became Professor Emeritus. He served in Chemical Warfare Service Reserves from 1924 to 1942, then served actively as a Lt. Colonel from 1942 to 1945. Dr. Thompson was Chairman of the International Committee on Oceanography, Pacific Science Congress from 1936 to 1953, and Chairman of the Committee on

Oceanography of the National Research Council from 1935 to 1941. He was a member of the National Academy of Sciences, and in 1948 was awarded the Academy's Agassiz Gold Medal. He had been a member of the AGU since 1930, serving as President of the Section of Oceanography from 1935 to 1938.

Union, Section, and Committee Activities

Union and Section Committees

COUNCIL OF THE UNION

Thomas F. Malone, President; George P. Woollard, Vice President; A. Nelson Sayre, General Secretary; Waldo E. Smith, Executive Secretary; William C. Ackermann, K. Hilding Beij, Lloyd V. Berkner, Detlev W. Bronk, Perry Byerly, Horace R. Byers, C. T. Elvey, Edward B. Espenshade, Willis B. Foster, David T. Griggs, Harry H. Hess, Floyd W. Hough, J. Wallace Joyce, Joseph Kaplan, W. D. Lambert, John Lyman, Gordon A. Macdonald, Walter H. Munk, Morris Neiburger, Thomas B. Nolan, C. L. Pekeris, James A. Peoples, Jr., Donald Pritchard, F. W. Reichelderfer, L. B. Slichter, E. H. Vestine, Charles A. Whitten, H. G. Wilm, Hatten S. Yoder, Jr.

EXECUTIVE COMMITTEE OF THE COUNCIL

Thomas F. Malone, President; George P. Woollard, Vice President; A. Nelson Sayre, General Secretary; J. Wallace Joyce, Secretary for International Participation; Lloyd V. Berkner, Joseph Kaplan, Donald W. Pritchard, F. W. Reichelderfer, Charles A. Whitten

STANDING COMMITTEES OF THE UNION

International Participation—J. Wallace Joyce, Chairman; Lloyd V. Berkner, Maurice Ewing, Joseph Kaplan, Walter Langbein, Leonard M. Murphy, Charles A. Whitten

Statutes and By Laws—Walter B. Langbein, Chairman; A. J. Dessler, Irving Friedman

Membership—Earl G. Droessler, Chairman; Willis B. Foster, John R. Gerhardt, Elliott B. Roberts

Eastern National Meeting—Leroy R. Alldredge, Chairman; John Lyman, Leonard M. Murphy, S. F. Singer

Western National Meeting—Joseph Kaplan, Chairman; W. W. Kellogg, Secretary; Eugene Bolla, Perry Byerly, Philip E. Church, C. T. Elvey, Bernhard Haurwitz, Robert E. Holzer, J. A. Jacobs, Gordon J. F. MacDonald, Walter H. Munk, Melvin J. Ord, Saul Price, Victor H. Regener, Alan H. Shapley, E. J. Workman

Nominations—E. H. Vestine, Chairman; Harry H. Hess, Alfred O. C. Nier
Budget—Louis O. Quam, Chairman; Howard A. Meyerhoff, C. F. Stewart Sharpe
Audit—A. G. McNish, Chairman; Albert P. Crary, Elliott B. Roberts

SPECIAL COMMITTEES AND BOARDS OF THE UNION

Geophysical and Geological Study of Continents
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Cosmic-Terrestrial Relationships—Walter O. Roberts, Chairman; Robert Bracewell, Joseph W. Chamberlain, C. T. Elvey, John Wainwright Evans, Herbert Friedman, Sigmund Frits, H. K. Kallmann, Serge A. Korff, Robert R. McMath, Millett G. Morgan, Hugh Odishaw, Clarence E. Palmer, Alan H. Shapley, S. F. Singer, Thomas L. Skillman, Joseph A. Smagorinsky, E. H. Vestine, Arthur H. Waynick, Fred L. Whipple, Hurd C. Willett

Planning on Planetary Sciences—Homer E. Newell, Jr., Chairman; Robert Jastrow, Secretary; Philip H. Abelson, Leroy R. Alldredge, Joseph W. Chamberlain, Thomas Gold, Gordon J. F. MacDonald, Hugh Odishaw, Alan H. Shapley, E. H. Vestine, Harry Wexler, Charles A. Whitten

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Russian Translation Board—Perry Byerly, Chairman; Werner A. Baum, W. S. Jardetsky, Walter B. Langbein, John Lyman, F. W. Reichelderfer, Adrian E. Scheidegger, Waldo E. Smith, Victor Vacquier

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Study of the Metric System—Lansing G. Simmons, Chairman; Carl I. Aslakson, Finn E. Bronner, John G. Ferris, Floyd W. Hough, Helmut E. Landsberg, G. Medina, John A. O'Keefe, Milton O. Schmidt, Julius L. Speert, Lewis V. Judson, Consultant

Resolutions—Helmut E. Landsberg, Chairman; David T. Griggs, Norman A. Haskell, Elliott B. Roberts

Promotion—Earl G. Droessler, Chairman; Philip H. Abelson, James R. Balsley, Hugh Odishaw

Education—Appointments pending
Tellers—James N. Jordan, Chairman; Leslie F. Bailey, Bernard C. Byrnes, Elizabeth R. King,

James F. Lander, G. Edward Manger, Robert W. Seston, Harris B. Stewart, Jr.
 Award of the William Bowie Medal—Maurice Ewing, Chairman; Leason H. Adams, Gordon J. F. MacDonald
 John A. Fleming Award—Frederick J. Agnich, Chairman; Ross Gunn, E. H. Vestine
 James B. Macelwane Award—Earl G. Droessler, Chairman; Victor J. Blum, S.J., Perry Byerly, Maurice Ewing, Joseph Kaplan, Kenneth C. Spengler
 Study of Awards—Earl G. Droessler, Chairman; Leason H. Adams, Frederick J. Agnich, Walter H. Bucher, Earl Ingerson
 Education—Appointments pending

REGIONAL COMMITTEES

Pacific Northwest—Robert Beaumont, Chairman; Hollis Orem, Secretary-Treasurer
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 Representing Seismology and Tectonophysics—Robert de Lucia
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 Representing Geomagnetism and Aeronomy, and Volcanology, Geochemistry, and Petrology—Keith E. Anderson
 Representing Oceanography—Robert Paquette
 Representing Hydrology—Charles L. Barker, Hollis Orem, Meredith Thoms
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 Representing Meteorology—W. D. Duthie, Robert E. Holzer, Morris Neiburger
 Representing Geomagnetism and Aeronomy—E. H. Vestine
 Representing Oceanography—Charles S. Cox, Jacob B. Wickham
 Representing Hydrology—Arthur F. Pillsbury, Joseph F. Poland, David K. Todd
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REPRESENTATIVES

NAS-NRC, Division of Earth Sciences—Frank Press
 NAS-NRC, Division of Physical Sciences—L. T. Aldrich
 NAS-NRC, Office of Critical Tables—George R. Tilton
 American Association for the Advancement of Science, Council—Martin A. Pomerantz, Walter Orr Roberts
 American Geological Institute—James R. Balsley, James A. Peoples, Jr.

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Executive Committee—Floyd W. Hough, Chairman; Buford K. Meade, Charles

Pierce, Charles A. Whitten
 International Participation—William Markowitz, Chairman; Carl I. Aslakson, Claude F. Gilchrist, David L. Mills
 Resolutions—Julius L. Speert, Chairman; A. Edward Craig, Albert J. Hoskinson
 Program—Erwin Schmid, Chairman; Soren W. Henriksen, John A. O'Keefe, Ernest J. Parkin, Donald A. Rice
 Scientific Papers—Roman K. C. Johns, Chairman; Mrs. Irene Fischer, William M. Kaula, Milton O. Schmidt
 Nominations—Charles Pierce, Chairman; Harry H. Hess, Milton O. Schmidt

Seismology

Executive Committee—James A. Peoples, Jr., Chairman; Benjamin F. Howell, Jr., Jack Oliver, Stewart Smith
 International Participation—Leonard M. Murphy, Chairman; Norman A. Haskell, Jack Oliver
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 Nominations—Hugo Benioff, Chairman; P. E. Byerly, Dean Carder

Meteorology

Executive Committee—Morris Neiburger, Chairman; Henry G. Houghton, Woodrow C. Jacobs, Helmut Landsberg, Thomas F. Malone
 International Participation—Helmut Landsberg, Chairman; W. W. Kellogg, Vice Chairman; H. R. Byers, J. G. Charney, Herbert Riehl, Morton G. Wurtele
 Atmospheric Chemistry—James P. Lodge, Chairman; Richard D. Cadle, W. D. Crozier, Samuel Epstein, Joshua Z. Holland
 Atmospheric Electricity—Marx Brook, Chairman; Seville Chapman, John F. Clark, Donald R. Fitzgerald, Heinz W. Kasemir, Bernard Vonnegut
 Atmospheric Radiation and Optics—Lewis D. Kaplan, Chairman; A. J. Drummond, Richard Goody, W. L. Godson, R. Pennndorf, Z. Sekera
 Atmospheric Turbulence and Diffusion—Willem Malkus, Chairman; Harrison E. Cramer, E. Wendell Hewson, Glenn R. Hilst, Maynard E. Smith
 Bioclimatology—Frederick Sargent II, Chairman; Konrad J. K. Buettner, A. Nelson Dingle, Igho H. Kornblush, James K. McGuire, Robert A. Ragotzkie
 Cloud Physics—Helmut Weickmann, Chairman; Roscoe R. Braham, Dwight Kline, Wendell Mordy, Vincent J. Schaefer
 Dynamics of Large- and Medium-Scale Atmospheric Motions—Jule G. Charney, Chairman; George S. Benton, Manfred M. Holl, Robert R. Long, Jerome Namias, Richard J. Reed, Phillip D. Thompson

Interaction of the Atmosphere with the Sea
(joint Committee with the Section of Oceanography and the American Meteorological Society)—Robert G. Fleagle, Chairman;
C. D. Keeling, Joanne S. Malkus, P. G. Neumann, R. O. Reid, W. S. von Arx

Meteorological Statistics and Data Handling
—John C. Bellamy, Chairman; G. W. Brier, Joseph G. Bryan, Edward N. Lorenz, William C. Spreen, Leo J. Tick, Paul M. Wolff
Paleoclimatology and Climatic Change—Reid A. Bryson, Chairman; William L. Donn, J. Murray Mitchell, Jr., Paul B. Sears, Terah L. Smiley, Hurd C. Willett

Planetary Atmospheres—Yale Mintz, Chairman; Arnold H. Glazer, Richard Goody, Bernhard Haurwitz, Seymour Hess, Carl Sagan, W. M. Sinton, John Strong

Polar Meteorology (Arctic and Antarctic)—Harry Wexler, Chairman; Franklin I. Badgley, Arthur D. Belmont, F. Kenneth Hare, Thomas J. Keegan, William B. Moreland, Morton J. Rubin

Satellite Meteorology—Sigmund Frits, Chairman; W. G. Stroud, Verner E. Suomi, John F. Tatom, Delbert G. Van Ornum, William K. Widger

Tropical Meteorology—Herbert Riehl, Chairman; C. L. Jordan, Joanne S. Malkus, C. S. Ramage, R. H. Simpson

Upper Atmosphere—W. W. Kellogg, Chairman; Richard Goody, Wayne S. Hering, F. S. Johnson, Adam Kechanski, George Ohring, Gerhard F. Schilling

Water Resources—Ray K. Linsley, Chairman; George S. Benton, Luna B. Leopold, J. E. McDonald, Glenn E. Stout, Gilbert F. White

Meetings—W. E. Hiatt, Chairman; J. L. Paulhus, Vice Chairman; W. Best, J. E. Caskey, G. D. Hughes, Conrad Mook, J. C. Thompson, J. C. West, Harry Wexler

Nominations—Appointments deferred

Geomagnetism and Aeronomy

Executive Committee—C. T. Elvey, Chairman; Leroy R. Aldredge, J. H. Nelson, E. H. Vestine

International Participation—L. R. Aldredge, C. T. Elvey, J. H. Nelson, E. H. Vestine, other appointments pending

International Quiet Sun Year—R. A. Helliwell, Chairman; J. W. Chamberlain, J. P. Heppner, F. S. Johnson, F. E. Roach, M. Sugiura

Nominations—Appointments deferred

Oceanography

Executive Committee—D. W. Pritchard, Chairman; Robert S. Arthur, Arthur E. Maxwell, Walter H. Munk

International Participation—John Lyman, Chairman; Arthur E. Maxwell, Harris B. Stewart

Interaction of the Atmosphere with the Sea
(joint Committee with the Section of Meteorology and the American Meteorological Society)—Robert G. Fleagle, Chairman;
C. D. Keeling, Joanne S. Malkus, P. G. Neumann, R. O. Reid, W. S. von Arx

Resolutions—Appointments deferred

Nominations—Appointments deferred

Volcanology, Geochemistry, and Petrology

Executive Committee—H. S. Yoder, Jr., Chairman; H. L. Foster, E. D. Goldberg, A. O. C. Nier, D. R. Wones

International Participation—L. T. Aldrich, Chairman; P. H. Abelson, Irving Friedman, J. F. Schairer

Resolutions—Appointments deferred

Nominations—Appointments deferred

Hydrology

Executive Committee—William C. Ackermann, President; David K. Todd, Vice President; Ralph N. Wilson, Secretary and Secretary for International Participation; Walter B. Langbein, Past President; R. T. Beaumont, at large; Harry E. Schwarz, Washington Program Chairman; Arvi O. Waananen, Western Program Chairman; Henry W. Anderson, Local Representative for IUGG at Berkeley; Tor J. Nordenson, Publication Liaison; Mark F. Meier, Publication Liaison; H. G. Wilm, as Honorary President, International Association of Hydrology; A. Nelson Sayre, ex officio; Waldo E. Smith, ex officio

International Participation—Executive Committee, with Ralph N. Wilson designated as Secretary

Program, Washington National Meeting—Harry E. Schwarz, Chairman

Program, Western National Meeting—Arvi O. Waananen, Chairman

Nominations—W. E. Hiatt, Chairman; C. C. McDonald, J. I. Perrey

Resolutions—Walter B. Langbein, Chairman; J. B. Franzini, Floyd A. Huff

Awards—David K. Todd, Chairman; James A. Bender, Walton H. Durum, David M. Hershfield, Edward A. Johnson, Philip E. LaMoreaux, Mark F. Meier, W. J. Roberts, C. H. M. van Bavel, M. Gordon Wolman

Representative for Bulletin of International Association of Hydrology—Mrs. Ethel W. Coffay

Precipitation—David M. Hershfield, Chairman; Roger Betson, Leon E. Borgman, Arnold Court, Fred W. Decker, Joel E. Fletcher, C. S. Gilman, James C. Neill, Richard A. Schleusener, Walter T. Wilson

Evaporation and Transpiration—W. J. Roberts, Chairman; Franklin I. Badgley, Wallace W. Lamoreux, Leonard Longacre, Robert A. Merriam, Paul R. Nixon, James H. Patric, T. E. A. van Hylekama

Erosion and Sedimentation—M. Gordon Wolman, Chairman; Henry Anderson, Elliott M. Flaxman, Herman G. Heinemann, Thomas Maddock, Carl Miller, John W. Roehl

Surface Water—Edward A. Johnson, Chairman; Charles D. Hopkins, Jr., L. L. Kelly, Lawrence A. Mullnix, H. C. Riggs, P. B. Rowe, Willard M. Snyder, John B. Stall, Paul J. Zinke

Ground Water—Philip E. LaMoreaux, Chairman; Jose A. da Costa, Vice Chairman; John F. Mann, Joseph F. Poland, H. E. Skibitzke, William C. Walton

Geochemistry of Water—Walton H. Durum, Chairman; R. M. Garrels, Edward D. Goldberg, John D. Hem, Joseph Lieberman, Lester Machta, Joseph E. Upson

Physics of Soil Moisture—C. H. M. van Bavel,

Chairman; Joseph B. Franzini, John D. Isherwood, Arnold Klute, James N. Luthin, Irwin Remson, W. O. Smith, Dale Swartzendruber

Glaciers—Mark F. Meier, Chairman; Henri Bader, Charles R. Bentley, William D. Field, Calvin J. Heusser, E. R. La Chapelle, R. P. Sharp, J. Weertman, Harry Wexler
Snow and Ice—James A. Bender, Chairman; Whitney M. Borland, Eugene L. Peck, J. Weertman

Tectonophysics

Executive Committee—Louis B. Slichter, Chairman; Iris Y. P. Borg, David T. Griggs, H. H. Hess, Victor Vaquier

International Participation—Appointments deferred

Nominations—Appointments deferred

VII General Assembly Pan American Institute of Geography and History

The VII General Assembly of the Pan American Institute of Geography and History was held in Buenos Aires, August 1-15, 1961. The VI Consultation on Geography, the V Consultation on History, and the IX Consultation on Cartography were held at the same time, these groups constituting the working commissions of the Institute. The American Geophysical Union was represented by Elliott B. Roberts and Charles A. Whitten, who have submitted the following report.

"The work within the Commission on Cartography is of primary interest for the purposes of this report. It is divided among nine committees: Geodesy, Gravimetry and Geomagnetism, Seismology, Topographic Mapping and Photogrammetry, Aeronautical Charts, Hydrography, Tides, Special Maps, and Urban Surveys. A special resolution adopted at Buenos Aires provided for dividing the Committee on Gravimetry and Geomagnetism into two committees—(a) Gravity and Earth Tides and, (b) Geomagnetism and Aeronomy.

"Twenty-two countries of the Western Hemisphere sent delegates and advisers to this international meeting. These participants were representatives of federal agencies and institutes engaged in geophysical, cartographic, geographic, historical, and cultural studies.

"The chief delegate from the United States was Dr. Arch C. Gerlach, Map Division, Library of Congress; US Delegate to the Commission on

Geography was Dr. Clarence F. Jones, Northwestern University, Evanston, Illinois; US Delegate to the Commission on History was Dr. Robert N. Burr, University of California, Los Angeles, California, and the US delegate to the Commission on Cartography was Col. Frederick C. Diercks, former Commanding Officer, Army Map Service.

"The officers elected to serve until the next General Assembly are: President of the Institute, General Victor N. J. Hosking, Argentina; President of Commission on Cartography, General Juan Jose Nano, Argentina; President of Commission on Geography, Dr. Fabio de Macedo Soares Guimaraes, Brazil, and the President of Commission on History, Dr. Silvio Zavala, Mexico.

"This general assembly provided the opportunity for the representatives of various agencies to coordinate their scientific and engineering activities. It also provided the opportunity for discussing new techniques and developments in the operations of the work for which these agencies are responsible. Numerous resolutions were adopted which will serve as guide lines toward more effective international cooperation in our geophysical and cartographic programs.

"An intangible, and yet, perhaps, the most valuable result of such meetings is the development of friendly relationships, thus providing a better understanding for those who are working in these scientific fields in neighboring countries."

SPECIAL ANNOUNCEMENTS

• **PACIFIC SOUTHWEST REGIONAL MEETING**—The Pacific Southwest Regional Meeting of the AGU will be held in Tucson, Arizona, January 31, February 1 and 2, 1962. The program for the first day will include a general session with invited speakers, a session on micrometeorology, social hour, and the evening banquet at which Gerald Kuiper will be the featured speaker.

Sessions on thunderstorm electricity, and on groundwater hydrology, are scheduled for the second day; and other sessions that day will be determined by contributed papers.

February 2 will be devoted to two tours. Tour 1 will be to Tombstone, Arizona, Walnut Gulch Experimental Watershed, and Nogales, Mexico. Tour 2 will be through Arizona-Sonora Desert Museum, with other stops of hydrological and geological interest, terminating at Kitt Peak National Observatory.

Announcements have already been sent to those in the area. C. H. M. van Bavel, US Water Conservation Laboratory, Route 2, Box 816-A, Tempe, Arizona, is in charge of the meeting.

• **FORTY-THIRD ANNUAL MEETING OF THE AGU, APRIL 25 THROUGH 28, 1962, IN WASHINGTON, D. C.**—The 43rd Annual Meeting, planned for the above dates, will immediately follow the annual meeting of the National Academy of Sciences.

The smoker will be Wednesday evening, April 25; other meetings of the Union will include a business session, and the presentation of the William Bowie Medal at an evening meeting. Suggestions for Union meetings are welcome. Send them to Leroy R. Alldredge, Chairman, Committee on the Eastern National Meeting, 10500 Royal Road, Silver Spring, Maryland.

To obtain information regarding Section meetings, or to offer suggestions for specific programs, write to the Section secretaries or program chairmen listed below.

Members and nonmembers are invited to submit papers for consideration. Titles of papers with three copies of abstracts should be sent as soon as possible, and not later than *February 1, 1962*. (The closing date for Hydrology is *January 2, 1962*, and for Meteorology, *January 9, 1962*. See below.) Include the time required for presentation of your paper (most papers are allowed from 10 to 20 minutes), and what projection equipment will be needed. Standard slide projectors ($3\frac{1}{2} \times 4$ inches) will normally be available at the meetings. When making slides, avoid crowding or attempting to show too much on one slide. More than two or three curves on a slide are confusing. Large lettering is essential.

If a paper is written in collaboration, please indicate which author will present it. Arrangements

can sometimes be made for the presentation of papers by authors who cannot attend, but no papers will be presented by title only.

Section program planners may close filled programs before the deadline dates indicated, so please send word early. Specific themes are being developed in some sections; if a particular paper does not fall within the themes, and if the sessions for general papers are already closed, such papers may be refused. Abstracts of papers that are to be presented will be published in the program. Remember that the editors must have *double-spaced, ribbon copies* of abstracts.

An abstract is an opportunity to bring the important results of your work to the attention of all those who read the program. The abstract should be concise and comprehensive, and must not exceed 200 words. Longer abstracts will be reduced to 200 words, or omitted, at the editors' discretion.

Complete manuscripts are not necessary but are desired and should be forwarded to the office of AGU by April 15, for use by science news writers. Authors themselves are the best judges of whether their papers will interest the general public. Please indicate whether the paper is being submitted for the program only, or also for consideration for publication in the *Journal of Geophysical Research*.

Make hotel or room arrangements early, directly with the hotel of your choice. If you fail on the first attempt, remember that advance bookings that are not taken up are generally canceled by hotels about two weeks in advance. Thus a follow-up request about mid-April may bring a desired response. We have block bookings at the

Roger Smith Hotel, Pennsylvania Avenue at 18th Street, N.W.

Willard Hotel, Pennsylvania Avenue at 14th Street, N.W.

If you write to one of these hotels refer to the AGU block booking.

Abstracts and supplemental information should be sent to the office of AGU at 1515 Massachusetts Avenue, N.W., Washington 5, D. C., or to the secretary or program chairman of the appropriate Section as follows:

Geodesy, Buford K. Meade, US Coast and Geodetic Survey, Washington 25, D. C., or Erwin Schmid (Program Chairman), US Coast and Geodetic Survey, Washington 25, D. C.

Seismology, Benjamin F. Howell, Jr., Geophysical Laboratory, Mineral Sciences Building, Pennsylvania State University, University Park, Pennsylvania.

Meteorology, Woodrow C. Jacobs, 3812 Nash Street, S.E., Washington 20, D. C., or William

Hiatt (Program Chairman), US Weather Bureau, Washington 25, D. C. This Section will meet jointly with the American Meteorological Society. Because of the large number of prospective participants, papers for this section will be carefully screened. Please submit both the abstract and a comprehensive summary of the paper before January 9. You will receive word before February 10 of whether you will be scheduled to present your paper.

Geomagnetism and Aeronomy, J. Hugh Nelson, Geophysics Division, US Coast and Geodetic Survey, Washington 25, D. C.

Oceanography, Arthur E. Maxwell, 5627 Potomac Avenue, N.W., Washington 16, D. C.

Volcanology, Geochemistry, and Petrology, David R. Wones, US Geological Survey, Washington 25, D. C.

Hydrology, Ralph N. Wilson, 3322 Stanford Drive, University Hills, West Hyattsville, Maryland, or Harry E. Schwarz (Program Chairman), 315 Ladson Road, Silver Spring, Maryland. To eliminate over-crowding the schedule, and yet allow a large number of hydrologists to present their work, a few papers will be selected for full-length presentation. The others will be presented as five-minute summaries. This procedure was used last year with good results. It allows detailed discussion of subjects of broad interest, and also provides for short presentation of other timely papers. The summary due on January 2 may be informal. The 200-word abstract (3 copies, double spaced) should reach Program Chairman Schwarz by February 3. The *ad hoc* Committee will notify each author by January 25 as to whether his paper is to be presented as a summary or in full. Those giving full-length presentations are asked to submit their complete papers to Mr. Schwarz before the beginning of the meeting.

Tectonophysics, Mrs. Iris Borg, Box 579, Livermore, California.

Planetary Sciences—The Planning Committee on Planetary Sciences will participate in the Annual Meeting. Submit abstracts, before the February 1 deadline, to A. G. W. Cameron, Institute for Space Study, 475 Riverside Drive, New York 27, New York.

• **SYMPOSIUM ON USE OF ARTIFICIAL SATELLITES FOR GEODETIC PURPOSES**—COSPAR and the IUGG, in cooperation with the Section of Geodesy of the AGU, will sponsor the above symposium, to run concurrently with the AGU Annual Meeting, April 26-28, 1962, in Washington, D. C. Meetings will be held at the Naval Observatory, and will feature

primarily invited papers on dynamic and geometric applications, observing programs for optical and radio tracking, related problems of celestial mechanism, data reduction, and international participation. Chairman of the Planning Committee is William M. Kaula, 9608 Tuckerman Street, Seabrook, Maryland.

• **SYMPOSIUM ON THE VARIATIONS OF THE REGIME OF EXISTING GLACIERS AT OBERGÜTEL, AUSTRIA, SEPTEMBER, 1962**—American participation in the Symposium will be arranged through the Committee on Glaciers (Section of Hydrology) of the AGU. Information may be obtained from Mark F. Meier, Chairman, AGU Committee on Glaciers, US Geological Survey, 529 Perkins Building, Tacoma 2, Washington, or William O. Field, Vice-President of the International Commission of Snow and Ice, American Geographical Society, Broadway at 156th Street, New York 32, New York. Abstracts are due on January 1, 1962, and complete papers due on March 1, 1962. Papers of US scientists will be screened in this country.

The Symposium is sponsored by the International Union of Geodesy and Geophysics, the International Association of Scientific Hydrology, and the Commission of Snow and Ice.

• **SYMPOSIUM ON VOLCANOLOGY IN JAPAN**—An International Symposium on Volcanology, to be held in Tokyo May 9 through 19, 1962, is being planned by the Science Council of Japan, the Volcanological Society of Japan, the International Association of Volcanology, and the IUGG. Discussions planned include prediction of time and place of volcanic eruption, and relation between magmas and the nature of volcanic eruptions. Field trips will be held during the meeting, and post-meeting trips will be scheduled to Kyusyu Islands, Hokkaido Island, and O-sima Volcano. Further information can be obtained from the Secretary, Organizing Committee, International Symposium on Volcanology, Science Council of Japan, Ueno Park, Tokyo, Japan.

• **CIRCULARS AVAILABLE ON IUGG 13TH GENERAL ASSEMBLY**—Those interested in the Triennial Meeting of IUGG, to be held in Berkeley, California, August 19 through 31, 1963, may now obtain circulars concerning the meeting from the office of AGU, 1515 Massachusetts Avenue, N.W., Washington 5, D. C. Nationals of other countries than the US should contact their own national committees.

Watch Special Announcements in future issues of *Transactions* for more details.

NATIONAL ACADEMY OF SCIENCES

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 IGY BULLETIN

A monthly survey of plans, activities and findings in geophysics—with emphasis on United States contributions to the International Geophysical Year, International Geophysical Cooperation-1959, and similar international endeavors including the World Magnetic Survey, the Year of the Quiet Sun, the Indian Ocean Expedition, the Antarctic research program, and space exploration and research. Preparation and publication of the Bulletin is supported by the National Science Foundation.

Earth's Thermal Radiation Balance Preliminary Results from Explorer VII

The following material is based on a more-detailed report by V. E. Suomi, of the University of Wisconsin. The parent report appeared in NASA Technical Note D-608, Juno II Summary Project Report: Volume I, Explorer VII Satellite, July 1961. The next issue of the Bulletin will contain a report on more-recent analyses of the Explorer VII radiation-balance data.

Preliminary analysis of data obtained by the radiation-balance experiment aboard Explorer VII during the satellite's first eight months in orbit appears to indicate the existence of large-scale patterns of outward flow of radiation from the earth as well as a relationship between these patterns and large-scale weather features of the lower atmosphere. This experiment, one of five major IGY experiments aboard Explorer VII, was conducted under the direction of V. E. Suomi, University of Wisconsin.

Explorer VII (Fig. 1), carrying the largest and most diversified payload of all IGY satellites, was launched on October 13, 1959. (See *Bulletin No. 29* for further details about the satellite and its experiments.) The orbit achieved was almost exactly as planned, with perigee at approx-

imately 555 km and apogee at approximately 1090 km (about 345 and 675 statute miles, respectively); inclination 50°; and period about 101 minutes. This

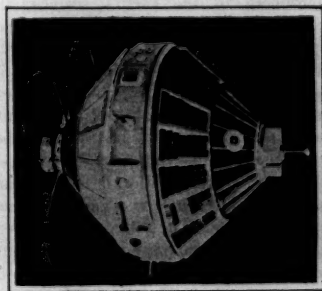


Fig. 1. Explorer VII (1959 Iota). This was the largest and most diversified of the US-IGY scientific satellites.

orbit is expected to give the satellite a lifetime of 20 years from launch. The radiation-balance experiment continued until August 19, 1961, when use of new data was discontinued because enough had already been accumulated to satisfy the requirements of the experiment.

General Background of Radiation-Balance Studies

The value of the sun's radiant energy at the mean distance of the earth's orbit is 2.00 calories/cm²/minute—the solar constant. The earth intercepts the sun's radiation as a disk and re-radiates it as a sphere; thus, if the earth were a perfect absorber, the average loss per cm² at equilibrium would be one fourth the solar constant, or 0.5 calorie/cm²/minute. The earth's surface is not a perfect absorber, however, and in addition, it is covered with an atmosphere in which part of the solar energy is reflected by scattering. That portion scattered toward the earth is seen as the blue sky.

Clouds, which act much as highly reflecting shutters, exercise the most important variable control on the amount of sunshine reaching the earth's surface. A small part of the sunlight is absorbed by gases in the atmosphere, principally water vapor and ozone. Most solar radiation that is not reflected, however, passes through the atmosphere to the earth's surface, the amount absorbed per unit area of surface depending on the sun's zenith angle and the surface properties. The oceans, for example, absorb about 95% of the radiation reaching them, while polar snow fields absorb only about 10%. Most land surfaces range between these extreme values.

Reflected solar radiation is lost to space and never enters into the global thermodynamic system. The remaining solar energy is absorbed mainly at the earth's surface, which acts as the "boiler lining" of the giant heat engine that drives the atmosphere and causes its motions. The solar input to each unit area of the earth's surface depends on latitude, time of year, and state of the atmosphere above. The effects of latitude and season on the incoming solar energy are well known, but atmospheric effects, especially over large parts of the earth for which weather observations are unavailable, can only be estimated.

Our understanding of the global distribu-

tion of the loss of long-wave energy to space is even less well known. Water vapor, carbon dioxide, ozone, and other minor gases in the atmosphere selectively absorb the long-wave energy radiated from the earth's surface and from other layers of the atmosphere, thus creating a very complex "greenhouse effect." The long-wave loss from the top of the atmosphere is three to four times as great as the net long-wave loss at the earth's surface. The atmosphere, then, acts as the principal heat sink whereas the earth's surface is the main heat source.

The long-wave heat loss from the atmosphere can be calculated when the vertical distribution of temperature and infrared radiation absorbers are known; such calculations have already been carried out by a number of workers.

These calculations are handicapped, however, by lack of complete global data on the vertical distributions of temperature and absorbers and, in particular, on the lack of adequate middle- and upper-air cloud-cover data. Until recently, meteorologists have been limited to viewing clouds from below and observing relatively small cloud areas at a time. Despite the observational shortcomings, these studies have clearly shown that parts of the earth are in radiation imbalance.

The tropics receive more energy from the sun than they lose by long-wave radiation to space. Conversely, the polar regions lose more energy to space by long-wave radiation than they gain from the sun. Since, on the average, the tropics are not warming and the polar regions are not cooling, the excess of heat in the tropics and the deficit in polar regions are balanced by poleward transport of heat by the atmosphere and the ocean currents. This poleward heat transport is a fundamental modifier of the world's weather.

These radiation balance studies assume that the earth as a whole is in radiational equilibrium with space, i.e., the total heat gain from the sun is just balanced by the loss to space. However, without qualifica-

tion, particularly with respect to periods considerably in excess of a year or extending to tens of years, this assumption would imply the lack of climatic change. The atmosphere does not have a large heat capacity to smooth out temporal imbalances. One worker has calculated, for example, that a change of only 1% in the amount of incoming solar energy would, if applied only to the atmosphere, cause a world-wide air-temperature change of 6°C (about 11°F). The oceans, on the other hand, have a much greater ability to store heat or provide the excess or deficit. A 1% change in the annual heat budget would change ocean temperatures only a few tenths of a degree in the surface layers and probably only a few thousandths of a degree at greater depths.

A fundamental question concerning the heat balance of the earth is whether there is a self-regulating mechanism. Such a mechanism might work as follows, for example: an increase in net global energy might cause more evaporation from the oceans, producing more clouds which would, however, give less solar input; this might then decrease evaporation, causing produc-

tion of fewer clouds and resulting in greater solar input, and so forth. The Explorer VII radiation experiment cannot provide a definite answer to this question since it could not obtain observations from the entire earth and, moreover, the orbit was not the best for this purpose; nevertheless, such satellite measurements are believed to be significantly more reliable than those of the past and thus represent a further step toward reaching an answer.

Instrumentation

The radiation sensors used in Explorer VII consisted of hemispheric radiation receivers, the equilibrium temperatures of which were measured by variable resistance elements, or thermistors. Sensor temperatures were telemetered to the receiving stations on earth. Then, by means of heat balance equations, the fluxes, or radiation currents, of both incoming and reflected solar radiation, and of terrestrial re-radiation could be computed from the observed sensor temperatures.

In this instrument system, four thin, hollow, silver hemispheres are mounted on

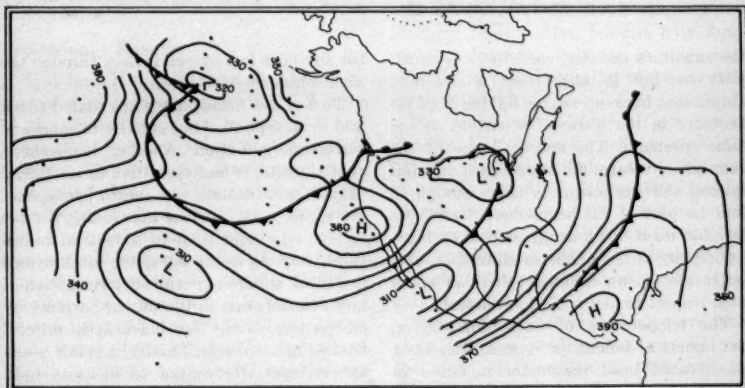


Fig. 2. Long-Wave Radiation Loss from Northern Western Hemisphere, December 2, 1969, as Determined from Explorer VII Measurements. Radiation values in calories/cm²/minute; dotted lines represent orbital path. (Compare with Fig. 4.)

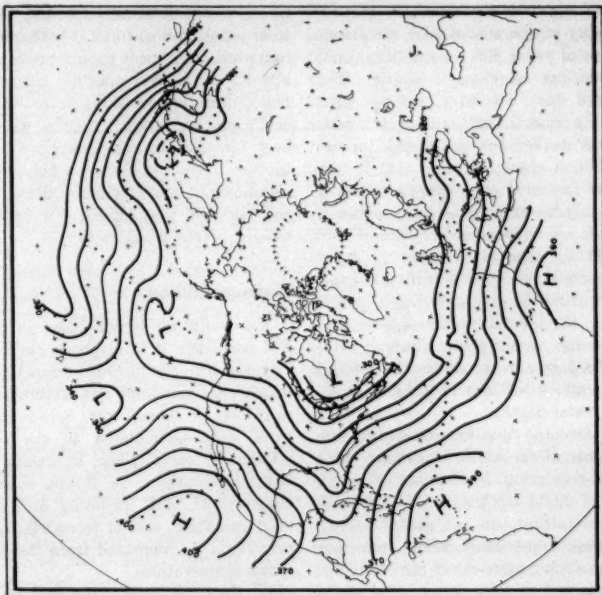


Fig. 3. Long-Wave Radiation Loss from Northern Hemisphere, April 4, 1980, as Determined from Explorer VII Measurements. Radiation values in calories/cm²/minute; dotted lines represent orbital path. (Compare with Fig. 5.)

the satellite's equator, each in close proximity to, but isolated from, a specially aluminized back-up mirror having high reflectance in the ultraviolet portion of the solar spectrum. The mirror image of the hemisphere creates the appearance of a full sphere, and the mirror is large enough so that no part of the hemisphere "sees" the satellite itself. Such a mirror-backed hemisphere, by virtue of the satellite spin, acts essentially as an isolated sphere in space with respect to the radiation currents.

The temperature of each thin, silver, hemispherical bolometer is measured by a glass-coated bead thermistor mounted in close thermal contact with the hemisphere. Provision is also made to measure the temperatures of the mirrors in order to account

for any heat lost by conduction through the hemisphere mounting posts.

Two of the hemispheres are coated black and thus respond about equally to solar and terrestrial radiation. Another hemisphere, coated white, is more sensitive to terrestrial than to solar radiation. A fourth hemisphere has a gold metal surface that makes it more sensitive to solar than to terrestrial radiation. Mounted at the top of the satellite axis is a black sphere to permit determination of any deterioration in the mirror surfaces by comparison with the blackened, mirror-backed hemispheres. Finally, a small hemisphere, specially coated to measure only short wavelengths and equipped with a shade to protect it from direct sunlight, was included to measure reflected sunlight

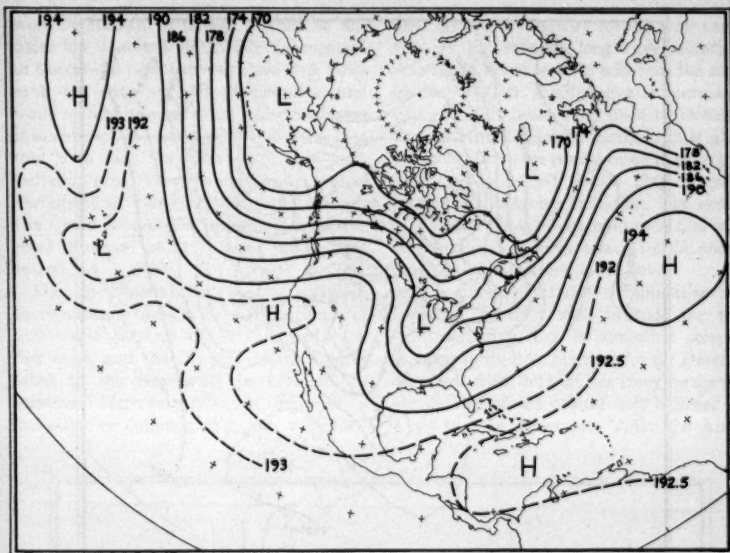


Fig. 4. Height of 600-millibar Surface over Part of Northern Hemisphere, December 2, 1959, at 0000 UT. Heights equal values shown $\times 100$ feet. (Compare with Fig. 2.)

when the axis of the satellite points to the earth's surface.

Preliminary Results

Explorer VII's perigee altitude of 555 km, normally keeps it well above the F-2 layer of the ionosphere when in daylight and above the F layer when in the earth's shadow. The satellite's transmitter operated at 19.995 mc, and the quality of the received signal had a marked day-night variation. On the night side of the earth, useful signals could be received for 15 to 20 minutes, or more, while the satellite travelled over an orbital arc up to 1/5 the distance around the earth. On the sunlit side, however, where the ionosphere is less transparent to radio waves, useful signals were received over only about 1/2 to 2/3 this distance. Thus, the data collected for nighttime hours gives more extensive coverage

than those for daytime hours, and therefore have been used to obtain the following preliminary results. Also, because only long-wave, or infrared, radiation is being considered, the calculations for nighttime data are much simpler.

The radius of the circle of coverage of Explorer VII's radiation sensors is roughly 23° of equatorial latitude (about 2500 km) at perigee and 31.5° (about 3500 km) at apogee. However, half the radiation power is received from an area below the satellite with a radius of only 5.3° of equatorial latitude (595 km) at perigee and 9° (1015 km) at apogee.

Figures 2 and 3 show the long-wave radiation loss measured by Explorer VII for the night of December 2, 1959, and for the night of April 4, 1960. Each dot along the orbital path represents one observation. The map cannot be given a specific synoptic

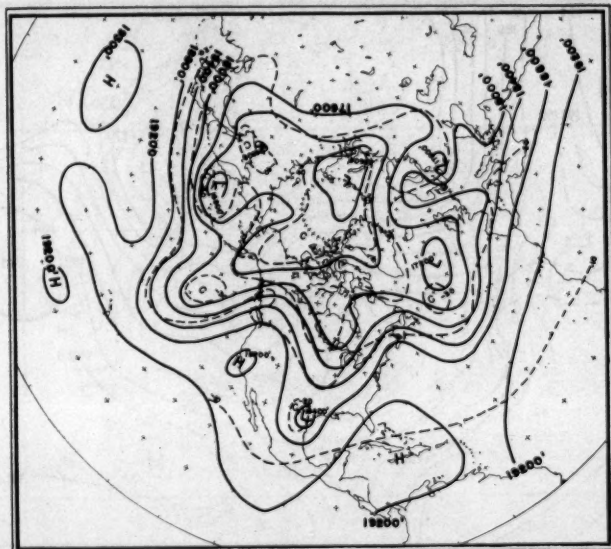


Fig. 5. Height of 500-millibar Surface over Northern Hemisphere, April 4, 1980, at 0000 UT. (Compare with Fig. 3.)

time because each pass of the satellite is 101 minutes later than the previous one, and times on opposite sides of the map are 12 hours apart. Because the Explorer VII orbit is inclined 50° to the equator, local time does not change with longitude as it does on a typical synoptic chart but instead it is a function of latitude. In the December series, the satellite came out of sunlight at the northern portion of the orbital belt and re-entered it in the southern hemisphere. In the April series, the reverse is true.

Surface and 500-mb weather maps having the best time relationships to the satellite's passes over the United States were chosen for comparison with the maps of long-wave radiation loss. The map analyses were obtained from the US Weather Bureau Northern Hemisphere maps. In principal, only one point on each satellite map is synchronous in time with the corresponding

500-mb synoptic map (Figures 4 and 5) and with the surface-analysis map (Figure 6). By using several surface maps it was possible to make the frontal positions included on the December radiation map synoptic with the satellite passage in the area. The 500-mb map for April 4 also contains isotherms (dashed lines).

In middle latitudes, where the telemetry contact is most reliable, analyses of the radiation pattern are more or less consistent from analyst to analyst. On the other hand, in the tropical Pacific, where telemetry coverage is not as good and the distance between orbits is great, analyses are subject to a considerable amount of individual interpretation. On the radiation map for December 2 (Fig. 2), for example, the orbital path SE along the Gulf of California very definitely establishes a low in outgoing radiation at 20°N . Similarly, the orbital path just

west of Hawaii definitely establishes another low at about 10°N . For the segment of the orbital path between these two, however, the data are not as complete, and while a trend toward a low value is shown, it is not certain, as the map indicates, that this is in fact the same large-scale low-radiation area. There is a general eastward movement of this outgoing radiation cell from map to map, in agreement with the wind direction at high levels during this season.

Despite uncertainties in the analysis, there appears to be a clear indication that large-scale patterns of outward radiation flux exist, and that these patterns are related to the large-scale features of the weather. Meteorologists had expected a variation of outgoing radiation with lati-

tude, but the preliminary results show variation of the outgoing long-wave radiation with longitude as well. In addition, the suggestion by C-G. Rossby several years ago that radiation loss is controlled by circulation patterns is clearly verified. It is also apparent that these results re-emphasize the important role that clouds play in controlling the outgoing radiation. The accuracy of estimates of outgoing radiation will be governed to a large extent by the accuracy of the estimate of cloud cover.

It is of some interest to note that the radiation gradient with latitude for the April radiation map is somewhat steeper than the latitudinal gradient for the December maps. Also, the heat loss from the northern portion of the orbital belt is lower in April than in December. Thus, the April

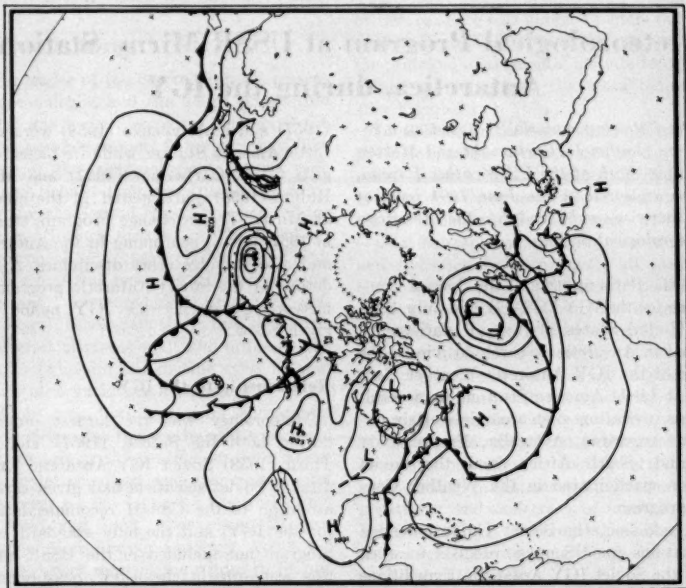


Fig. 6. Analysis of Surface Weather in the Northern Hemisphere, April 4, 1960, at 1200 UT. Fronts and centers of high (H) and low (L) pressure are shown. (Compare with Figs. 5 and 6.)

radiation pattern looks more like a winter situation than that for December. Inspection of the 500-mb charts shows that this apparent anomaly is explainable, however, since the north-south temperature gradient is steeper on the April map, and the temperature at the northern border is significantly lower as well.

Conclusion

The radiation charts discussed above represent only the beginning of analysis of an enormous amount of data. Also, they treat only half of the problem—the radiation losses. Equally important to our understanding of the earth's heat budget are the

radiation gains from the sun. These are being treated in continuing studies.

It appears from the preliminary results, that very useful radiation data can be collected using a modestly instrumented earth satellite. Inclusion of a data-storage unit, as in Tiros III (see *Bulletin No. 51*), so that the measurements for a complete orbit may be obtained by a ground station, makes possible the construction of radiation maps for the whole earth. The problem of analysis is thus made simpler, moreover, as it is no longer necessary to attempt to form a comprehensive picture by fitting together many pieces of scattered data. Instead, data are continuous and a comprehensive view of the earth's radiation balance can be more-readily obtained.

Meteorological Program at USSR Mirny Station, Antarctica, during the IGY

The following material is based on a report by Gordon D. Cartwright and Morton J. Rubin, both of the US Weather Bureau, which appeared in the June 1961 issue of Weatherwise, published by the American Meteorological Society.

At the Paris meeting of the Special Committee for the IGY (CSAGI), in July 1955, the United States invited all nations involved in Antarctic research to join in the work of the IGY Antarctic Weather Central at Little America Station. As a result of this invitation, meteorologists of six nations—Argentina, Australia, France, New Zealand, South Africa, and the Soviet Union—participated in the Weather Central program.

In addition, the Soviet Union extended invitations for US meteorologists to work with the Soviet IGY Antarctic Expeditions based at Mirny Station. During 1957 and 1958, Soviet Meteorologists V. I. Rastorguev

(1957) and P. Astapenko (1958) worked at Little America Station, while US meteorologists G. D. Cartwright (1957) and M. J. Rubin (1958) participated in the studies at Mirny. This exchange program, started in 1957, is still continuing in the Antarctic and also includes other disciplines. A few details of the Soviet Antarctic program in meteorology during the IGY period are given below.

Relationship to the IGY

Meteorology was the largest program during both the Second (1957) and the Third (1958) Soviet IGY Antarctic Expeditions. Soviet scientists had given careful attention to the CSAGI recommendations for the IGY, and the only standard IGY program not included in the USSR effort was atmospheric chemistry measurements (carbon dioxide and particulate matter). Glaciology, another large program, was

closely coordinated with meteorology. Frequent scientific meetings held during the winter helped stimulate interest in these interdisciplinary relationships. There was also full awareness of the interdependence of data taken by all countries working in the Antarctic, and intense interest was shown in the findings at other stations.

Of the USSR stations (see Table 1), Mirny, Oasis, and Vostok had the most consistent and most complete meteorological programs. Since the IGY, the following changes have taken place with respect to Soviet Antarctic Stations: Vostok-I was replaced by Vostok; Oasis, Pioneerskaya, and Sovetskaya have been discontinued; and Komsomolskaya has operated since early 1959 only as a summertime station. (The Lazarev station, at 69°58'S, 12°55'E, elevation 24 m, on the Princess Astrid Coast, was established on March 10, 1959.)

Program at Mirny

The leader of the Second Expedition was an oceanologist and the Third Expedition leader was a meteorologist; both gave the fullest possible support to meteorology. The heads of the meteorological groups were Oskar Krichak* (Forecast Institute of Moscow) for the Second Expedition and Viktor Bugaev (former director of the Tashkent Geophysical Observatory) for the Third. Each group was made up of several "synopticians," meteorologists (physical meteorology), aerologists (including specialists in aircraft observations), and ordinary observers (who did the routine synoptic and hourly observations and reporting).

Mirny was both the main operational headquarters for the continental expedition and its principal scientific station. About 190 Soviet scientists and technicians wintered over on the Antarctic Continent during 1957 and 1958, representing all geophysical disciplines and biology. About 125 of these spent most of the winter in Mirny,

at the edge of the continental ice sheet and just on the Antarctic Circle. The base was set up at a point on the Davis Sea where small rounded rocky outcrops keep the ice sheet immobile. Some buildings were actually sited on rock, others on the ice shelf. At the meteorological station, the gradient

Table 1. Station Data for USSR Antarctic IGY Stations

Station	Location	Height(m)
Mirny	66°33'S, 93°01'E	35
Oasis	66°16'S, 100°45'E	29
Pioneerskaya	69°44'S, 95°30'E	2700
Vostok-I	72°08'S, 96°35'E	3140
Vostok	78°27'S, 106°52'E	3420
Sovetskaya	78°24'S, 87°35'E	3570
Komsomolskaya	74°05'S, 97°29'E	3420

of the ice sheet was about 3 meters per 100 meters downward toward the sea, and all the principal instrumental installations were placed up-slope from the main buildings. (See Figure 7.)

In addition to the rawinsonde ascents and the usual surface synoptic and hourly (aviation) observations, the meteorological program at the three main Soviet stations included most of the following: radiation—total-hemispheric, diffuse, and direct—and radiation balance (net), all recorded continuously on multichannel recorders; wind, temperature, and humidity at selected heights from the surface to 10 meters (these were not continuously recorded in all cases, but observations were made regularly); sub-surface temperatures at closely spaced intervals down to 4 meters (similar measurements were carried out to greater depths in connection with the glaciological studies); snow-surface maximum and minimum temperatures; and collection of snow crystals (intermittently). Aerological observations from aircraft were among the special studies carried out at Mirny.

Table 2 gives average climatological data for Mirny for the years 1956–1958.

* Krichak and seven other men lost their lives in a fire at Mirny Station on August 3, 1960.

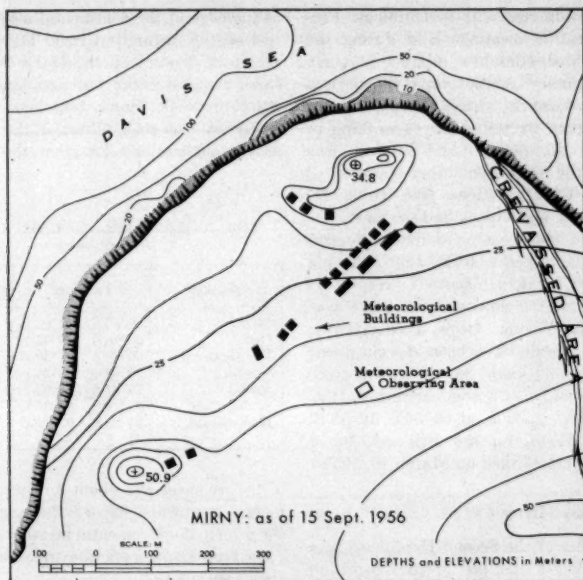


Fig. 7. Physical Setting of USSR Mirny IGY Station.

Airborne Meteorological Program

The airborne meteorological program was extensive. A two-engine aircraft was fitted out as a flying meteorological observatory to measure and record solar radiation; cloud density (optical measurements); total solar and sky radiation; reflected solar radiation; pressure, temperature, and relative humidity; air temperature; altitude; ice-crystal and cloud-drop samples; cloud forms; and surface phenomena.

On several occasions, equipment for measuring atmospheric-electricity phenomena was placed aboard and flights were carried out over the ocean, over the continental ice-cap, and through low- and middle-level clouds. The plane was also fitted with a mount for a vertically-oriented mapping camera.

In 10 months during 1958, seventeen

flights were made, usually with three observers aboard to attend to the instruments and to record the necessary data. Vertical soundings were made as the plane flew its course for distances usually ranging from 100 km over the ocean to 500 km or further over the continental regions. On a meteorological reconnaissance flight over the site of Vostok-I (April 22, 1958), 3140 meters above sea level, it was determined that the temperature was -52°C (-61.6°F) only 23 meters above the surface, while the temperature at 200 meters was -36°C (-32.8°F). The surface inversion was marked by a very thin ice-crystal fog—perhaps produced by the presence of the airplane, although the thin fog had been observed before the plane descended into the inversion—and the snow surface was somewhat obscured.

In other portions of the flight, it was

noted that the orientation of the primary sastrugi (snow-surface forms resulting from scouring and filling by the wind) reflected a prevailing surface wind from 110°, while a secondary orientation showed a wind from about 170°. In 1957, eight men wintered at the Vostok-I Station on their way to the geomagnetic pole and carried out a surface and upper-air observational program as well as glaciological observations. The mean temperature they recorded for June 1957 was -51.7°C (-61.1°F), the maximum was -30.5°C (-22.9°F), and the minimum was -67.8°C (-90.0°F).

Ice Reconnaissance Program

One of the unique programs carried out by both the Second and Third Soviet Antarctic expeditions was the regular monthly reconnaissance of the distribution of pack ice from the edge of continental ice to the edge of the pack ice, as much as 700 km from the base. This program was carried out by aircraft with special ice observers and meteorological observers on board. In some instances, the aircraft was also fitted with meteorographs to measure pressure, temperature, and relative humidity, and vertical soundings were made at the limit of flight over the sea.

Detailed and highly organized records of the character of the pack ice were kept by the ice observers, and these were compiled in the form of time analyses (monthly or bi-monthly) of ice features over the areas surveyed regularly by the aircraft. This information seemed to have an interesting correlation with the prevailing weather con-

ditions and a preliminary analysis of these features was undertaken during the Expedition. It was tentatively postulated by the chief of the meteorological group that variations in the position of edge of the pack ice, as well as its character in the region off Mirny, showed the effects of the prevailing distribution of cyclones and anticyclones in this area.

Automatic Weather Stations

In November 1958, an automatic weather station, reporting wind, pressure, and temperature data, was established on Drygalski Island ($65^{\circ}43'\text{S}$, $92^{\circ}30'\text{E}$), a 350-meter-high ice-dome over a submarine rise in the Davis Sea, some 75 km north of Mirny. The equipment transmitted air pressures over a 100-mb range, wind speeds from 1 to 16 meters per second, wind direction to 32 points, and temperatures from $+5^{\circ}$ to -88°C ($+42.8$ to -126.4°F).

On Drygalski Island, the sastrugi patterns showed that the prevailing winds were easterly. Orographically-induced low clouds and fog were common over the island. During the short period of occupation, 40-meter-per-second winds (90 mph) were experienced.

Earlier in the year, a similar automatic weather station had been hurriedly installed on the ice slope between Mirny and Pionerskaya Stations during a glaciological traverse. The equipment soon ceased transmitting, however, probably as a result of mechanical failure induced by the strong katabatic (downslope) winds and drifting snow so common in the region.

Table 2. Average Climatological Data: Mirny, 1956-1958

Measurement	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Mean Temp. ($^{\circ}\text{C}$)	-0.9	-4.8	-9.3	-11.4	-13.2	-17.1	-16.3	-18.1	-16.6	-13.2	-7.2	-2.4	-10.9
Max. Temp. ($^{\circ}\text{C}$)	+8	+3	-1	-1	0	-2	-4	-4	-2	-2	+5	+8	-8
Min. Temp. ($^{\circ}\text{C}$)	-9	-19	-20	-26	-27	-33	-36	-40	-33	-32	-18	-11	-40
Prev. Wind Dir.	107*	130*	133*	130*	127*	150*	123*	147*	117*	103*	123*	100*	124*
Mean Speed (Kts.)	16.9	10.2	22.0	27.6	28.1	26.4	28.7	28.3	26.0	20.2	19.4	15.7	23.2
Max. Speed (Kts.)	56	49	54	62	78	76	99	99	89	78	54	58	99
No. Days >29 Kts.	9	14	18	22	26	20	27	24	20	20	14	7	224
Pressure (Mb)	985.6	986.2	982.1	982.8	988.8	991.2	984.2	980.8	977.0	979.7	982.9	986.9	984.0

The Program at Oasis

The Soviet station at Oasis was of particular importance because of the unusual topographic features in its vicinity. These included an extensive area of exposed rock, virtually snow-free during most of the year and contiguous to a configuration of the continental ice sheet that produced especially strong winds under certain synoptic pressure distributions. The freezing and thawing of fresh-water lakes formed by the melt water from the continental ice sheet afforded a very interesting laboratory for study of the effects of seasonal radiation changes on the ice regime.

A full program of radiation measurements in various parts of the Oasis area was pursued by a small staff of six men. Soil temperature measurements at a number of depths also provided important data for the study of heat transfer to and from the fresh-water lakes and morainic material (mostly unsorted, glacier-deposited rock debris) that comprised most of the Oasis area. These programs were of particular interest in glaciological studies as well as in studies of frozen ground.

Climatic Conditions

Generally, temperature at Mirny (Table 2) is relatively mild for Antarctica, excluding the Palmer Peninsula. However, the relatively high frequency of strong winds makes difficult the task of meteorological observers and others who have to be out-of-doors. During the winter of 1958, there were 13 days with wind force above 60 knots. On one such occasion (July 23, 1958) the pressure fell 21 mb in six hours, and 36 mb in 24 hours. Safety lines were strung from meteorological headquarters to the observing site, some 200 meters upwind; later, lines were installed around the camp after two incidents in which men lost their way within the confines of the camp during blizzards.

The prevailing wind was between east and southeast, at an angle of about 30° to the main slope of the ice sheet; this also

was the direction of the strongest winds, which appear to result from the eastward passage of storm centers north of the station and the reinforcement of the gradient winds (horizontal winds tangent to constant-pressure-surface contours) by the katabatic effect. The use of a balloon-release tower greatly increased the number of successful launchings (only two observations were missed in two years because of hurricane force winds) even though some occasions required the launching of as many as four balloons before one was successful.

Stations on the high ice-dome, such as Vostok (see Table 3 for climatological data), Komsomolskaya, and Sovietskaya, were not bothered much by drifting snow as were the coastal and ice-slope stations. At the inland stations, difficulties arose from, and were associated with, high altitude and low temperatures that severely restricted strong and prolonged outdoor physical activities, and from long hours and months of darkness. Balloons for pilot and raob (radiosonde observation) ascents failed prematurely because of the low temperatures encountered from the surface to the stratosphere, although preconditioning the balloons with heat and diesel-fuel baths helped somewhat.

At Pioneerskaya station, as at Mirny and Oasis to a lesser extent, the strong winds and drifting snow made impossible the determination of how much snow was falling and how much was drifting. Crude equipment for measuring drifting snow was imprecise, and snow gauges were useless; only measurements of net accumulation against arrays of stakes gave reliable figures anywhere.

Results of Special Programs

A number of special studies were carried out by the members of the Soviet Antarctic Expeditions. These were meant to point out the character of the meteorological processes in the region and to help throw light on some exchange processes in respect to

Table 3. *Average Climatological Data: Vostok, 1958*

Measurement	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Mean Temp. (°C)	-31.3	-44.6	-55.9	-64.0	-62.9	-67.9	-65.3	-71.8	-66.3	-58.8	-43.2	-33.4	-55.4
Max. Temp. (°C)	-23	-29	-47	-43	-43	-47	-44	-55	-45	-41	-34	-26	-23
Min. Temp. (°C)	-41	-60	-67	-73	-78	-80.7	-81	-87.4*	-82	-71	-60	-44	-87.4*
Prev. Wind Dir.	180*	180*	220*	240*	240*	270*	240*	220*	250*	220*	220*	260*	228*
Mean Speed (Kts.)	8.9	7.2	9.9	7.8	10.1	9.5	9.7	9.1	10.5	27.8	8.1	7.4	8.9
Max. Speed (Kts.)	27	18	19	19	29	49	25	25	25	25	25	21	49
No. Days >29 Kts.	0	0	0	0	1	1	0	0	0	0	0	0	2
Pressure (Mb)	630.0	627.6	624.8	628.0	627.7	623.1	623.2	614.3	613.7	620.2	624.0	626.5	623.6

* World record minimum air temperature (-125.3°F), recorded August 25, 1958. On August 24, 1960, a new record minimum of -88.3°C (-126.9°F) was recorded.

the atmosphere-ocean-ice complex. Synoptic and climatological analyses, as well as the study of regional features, radiation balance, ice-mass movement, katabatic winds, and turbulent exchanges, have been reported on by Soviet Antarctic scientists. In general, they are similar to programs carried out by other countries. Two special studies, however, appear to be unique to the Soviet expedition—an airborne radiation program extending over a period of several years, and an airborne study of the atmospheric electrical field, carried out in 1958.

The airborne radiation program provided data for determining the short-wave radiation balance in the troposphere, the albedo of the underlying surface of the continental ice and the Davis Sea, and the albedo of clouds. Summertime mean values of atmospheric heating due to absorption of solar radiation were as shown in Table 4. Computations of cooling in the free atmosphere due to radiation under clear conditions gave about the same order of values as the radiative heating.

From the airplane observations, the mean value of the albedo of the ice slope was found to be 80% for sun heights of $25-35^{\circ}$; the albedo decreased as the solar altitude decreased, probably owing to snow sastrugi that shade the surface when the sun is low. The mean albedo of young sea ice was found to be 65%. Albedo of the open sea varied with roughness: in calm conditions with a sun height of 10° , the albedo was 33%; with small waves and sun height of 30° , it was

11%. The mean albedo of stratocumulus clouds, the most frequently observed cloud form over the sea, was 62%. Altocumulus clouds with a thickness of 250-300 meters had an albedo of 60%, while altostratus clouds, which predominate over the ice slope, had an average albedo of 40-60%.

Studies of the gradient of the earth's atmospheric electric field when pressure systems were over the ocean showed that the potential gradient is increased in the leading portion of a cyclone and in the rear of an anticyclone, and is decreased in the rear of a cyclone and in the leading portion of an anticyclone. Presumably, this is explained by the regime of vertical motions in the pressure systems. Middle- and upper-level clouds do not appear to affect the potential gradient, but lower clouds tend to decrease it by as much as 30%. On the continental surface itself, the principal variations in potential gradient result from wind conditions and cloudiness and include the monthly and annual variations. When wind speed increased from 10 to 70 knots, for example, the positive value of the gradient increased, but at wind speeds greater than 70 knots,

Table 4. *Summertime Mean Values of Atmospheric Heating, at Heights to 4 km, by Absorption of Solar Radiation.*

Surface	100 m-2 km	2-4 km
Open sea	0.034°C/hr	0.026°C/hr
Young sea ice	0.023°C/hr	0.010°C/hr
Continental ice-slope	—	0.033°C/hr

the potential gradient changed sharply in sign and value, reaching negative values of tens of thousands of volts per meter.

Large positive and negative values of space-charge density noted were several times greater than the space charges observed, in thunderstorms, elsewhere in the world. The sign of the space charge depended mainly on wind velocity, with large negative values observed at wind speeds above 70 knots. It was also noted that the current from sharp points during snowstorms tends to reduce the negative charge of the earth; this is contrary to measurements obtained from other continental regions, but supports data from Cambridge, England, for stormy periods.

Meteorological Rockets

A few meteorological rocket soundings were made from the Soviet research vessel

Ob during the 1957-58 supply season. Two of these were made at Mirny and others were at points around the periphery of East Antarctica and the Indian Ocean. These rockets reached heights of about 50 km (31 mi) and provided temperature, pressure, and wind data from the middle stratosphere.

Conclusion

The highlights described above illustrate the comprehensive and detailed character of the Soviet meteorology program in the Antarctic. The US scientists who worked at Mirny experienced effective working relationships and cordial personal associations with their Soviet colleagues during the periods of their individual assignments there. They found it both an interesting and rewarding experience that gave them a better understanding of Soviet science and scientists.

Explorer XIII Micrometeoroid Satellite

Explorer XIII (1961 Chi) was launched from NASA's Wallops Island Station, Virginia, at 2:29 pm EDT, August 25, 1961. The satellite carried five different types of micrometeoroid detectors designed to record and send back to earth information about the characteristics of micrometeoroids and their potential hazards to future spaceflight. The launch also served as a test of the performance, structural integrity, and environmental conditions of the all-solid-fuel, four-stage Scout launch vehicle and its guidance control system.

The planned orbit of the satellite was between 280 and 610 statute miles above the earth. While preliminary orbital calculations suggested that a stable orbit had been achieved, later data indicated an unexpectedly low perigee of 74 statute miles, resulting in the short lifetime for the satellite of $2\frac{1}{2}$ days. During this interval, Explorer

XIII transmitted 13 minutes (73,980 "bits") of data. The satellite re-entered the earth's atmosphere after a final transmission over Antofagasta, Chile, at 0200 UT, August 28, 1961. Orbital data were as follows: period, 97.5 minutes; apogee, 722 statute miles; perigee, 74 statute miles; and inclination, 37.7° .

Scout Launch Vehicle

The 72-foot, 36,600-lb, Scout launch vehicle, under development by the NASA Langley Research Center since mid-1958, is designed to provide the United States with a small, reliable, and flexible solid-fuel booster rocket for space-probe and orbital missions. (A description of the rocket appears in *Bulletin No. 46*.)

Early reports following the launch of Explorer XIII indicated that all stages of

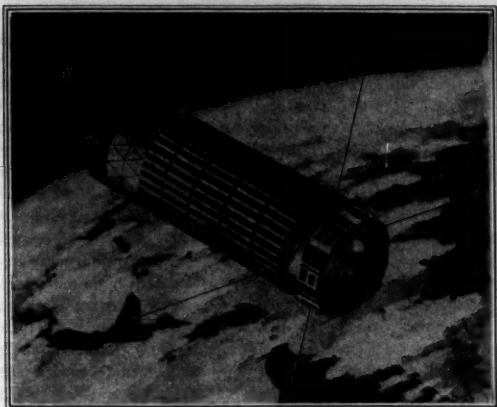


Fig. 8. *Explorer XIII Micrometeoroid Satellite.* Satellite structure is built around fourth-stage rocket. Five rows of cylinders around central portion are pressurized-cell detectors; triangles below them are grid detectors; squares near base are wire detectors. Larger blocks in nose and around forward portion of satellite are cadmium-sulphide impact detectors and smaller blocks in same areas are silicon solar cells. Dark trapezoidal area on nose, with circular window, is an impact sensor. NASA drawing.

the Scout vehicle performed as predicted, except for a pitch-up of the fourth stage at injection. It is believed that this deviation from expected performance caused the very low perigee responsible for the early demise of the satellite.

Payload Description

Explorer XIII was cylindrical in shape, about 24 inches in diameter, and approximately 76 inches long. The experimental equipment was built around the 18-inch-diameter, 72-inch-long fourth-stage of the Scout vehicle. A thin heat shield that protected the satellite during its ascent was later jettisoned into space, exposing the highly sensitive micrometeoroid detectors. (See Figure 8.)

Total weight of the satellite payload, including the various sensors, other scientific equipment, and mounting hardware, was about 127 lbs. Added to this were the fourth-stage rocket, the upper transition section connecting the fourth stage to the

third stage, and the spent spin motors, weighing a total of 63 lbs, for a total weight in orbit of nearly 190 lbs.

Micrometeoroid Experiments

Meteoroids, composed of iron, silicates, and other substances, are more numerous in interplanetary space than previously believed, and may impact a satellite at velocities ranging from 7-45 miles per second. Meteoroids usually burn as they fall through the atmosphere, and are then termed *meteors*. Those reaching the earth are *meteorites*. It is believed that several thousand tons of minute meteorites (micrometeorites, or micrometeoritic dust) may settle to the earth each day.

Meteoroids may be derived from the asteroids, which revolve about the sun in orbits between Mars and Jupiter. Those in elliptical orbits periodically cross the earth's path, and may impact on the earth or moon. Meteoroids may also be derived from comets, which revolve in highly eccentric orbits

around the sun and frequently approach relatively close to the earth.

The micrometeoroid detectors aboard Explorer XIII were designed to measure directly the puncture hazard to the structural skin of a spacecraft; micrometeoroid flux rates; and the erosion of spacecraft materials by small particles in space; and to record information affecting the design of solar cells for spacecraft power that would be more resistant to damage by particles and radiations in space.

The five types of detectors carried by the satellite (Fig. 8) included pressurized cells, foil gauges, and wire grids, providing a total surface area of $24\frac{1}{4}$ square feet exposed to micrometeoroid penetration; for impact detection, the satellite carried cadmium-sulphide cells and impact sensors having a combined total surface area of four square feet. Five groups of shingled, win-

dow-like silicon solar cells were placed on the nose of the satellite to determine, for future space experiments, the amount of protection such cells require. Two of these groups of solar cells were unprotected, 6-mil-thick glass slides covered the sensitive areas of two other groups of cells, and one group was protected by a 62-mil-thick quartz window.

Temperature measurements were made at selected places throughout the satellite, and a telemeter system with erectable antennas was located in the nose section to transmit data to ground receiving stations.

Despite Explorer XIII's short lifetime in orbit, some data were obtained from the micrometeoroid experiments aboard the satellite. Analysis of this data, conducted at NASA's Langley Research Center, may produce useful information on micrometeoroid hazards in the space around the earth.

World Warning Agency Report

Solar-Terrestrial Activity: January 1 - June 30, 1961

The following report, one of a series published periodically during and since the IGY/IGC period, is based on material issued by the World Warning Agency (AGIWARN), Fort Belvoir, Virginia, and on compilations of Solar-Geophysical Data issued by the Central Radio Propagation Laboratories (CRPL), Boulder, Colorado. Both AGIWARN and CRPL are administered by the US National Bureau of Standards.

A World Warning Agency report for the final quarter of 1960 appeared in Bulletin No. 47, which also contained a report on the new plan for Geophysical Alerts and Special World Intervals (SWI) developed for use during 1961-1962.

January 1—March 13, 1961

Of eight geomagnetic disturbances re-

corded by AGIWARN during the first quarter of 1961, five were sufficiently severe to warrant the issuance of World-wide Geophysical Alerts. Of these, Advance Alerts could be distributed effectively for only three; for the remaining five storms, lack of severity and unusual time of occurrence of the first K-figure of 5 or greater were the limiting factors. (The K-figure measures storm intensity on a scale of 0 to 9.) There were no major solar flares (class 3 or 3+) during the first quarter of 1961.

In terms of geomagnetic activity, none of the disturbances during this period could be classified as severe. However, associated with the eight magnetic storms that occurred in the 72-day period covered by this report were 16 days in which the magnetic field was disturbed and 23 days evaluated as unstable in terms of whole-day radio-quality indices.

The considerable amount of radio disturbance has resulted in deep concern over the growing problem of effective geomagnetic-storm prediction in this declining phase of the sunspot cycle. AGIWARN's experience in geomagnetic-storm prediction has shown that magnetically significant storms generally lend themselves to prediction more readily than minor storms. Major storms are often preceded by either observable solar activity of some nature or by a well-established pattern of recurrence at regular intervals.

The geomagnetic storms recorded in the first quarter of 1961 belong in the minor-storm category, and generally were not preceded by either of these major-storm indications. In fact, solar activity of the "event-type," observed so regularly during sunspot maximum and succeeding months, was practically non-existent during this interval. Consequently, anticipation of these storms through application of existing prediction techniques was generally not possible. Moreover, apparently anomalous characteristics of most of the storms—sudden commencements, lack of continuity, considerable variation in duration, etc.—greatly complicated post-storm analysis.

March 14—June 30, 1961

Four major solar flares occurred during the second quarter of 1961. Thirteen geomagnetic disturbances were recorded by AGIWARN in this interval, and World-wide Geophysical Alerts were issued for all but four. Of these, only two were classified as severe (storm A-index of about 50 or greater, on a scale of 0-400). Advance Geophysical Alerts were issued for four of the 13 storms, including both of the severe storms. Cosmic-ray and radio-disturbance effects associated with the severe storm of April 13 are shown in Figures 9 and 10.

Magnetic activity followed the general pattern to be expected in this declining portion of the sunspot cycle. During solar-quiet periods, most storms began gradually

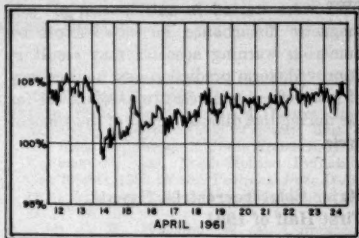


Fig. 9. Cosmic-Ray Indices for Mid-April 1961, Showing Forbush Decrease Associated with the Severe Magnetic Disturbances Beginning on April 13. From records of Deep River, Canada, neutron monitor.

and were of minor intensity. During active solar periods, the storms began suddenly, were associated with some particular event on the sun, and were of severe intensity.

The new plan for predicting intervals during which severe geomagnetic disturbance is expected (see *Bulletin No. 47*) was employed during this quarter. A predicted Special World Interval was declared once; although a storm subsequently began, it did not reach a severe level of intensity.

The new plan for Geophysical Alerts and SWI is coordinated through the International World Day Service. While the plan is similar to the IGY plan, under which

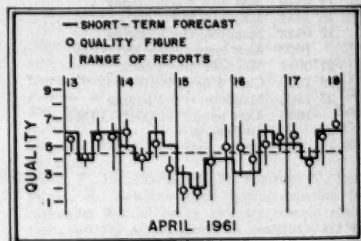


Fig. 10. Radio-Propagation Quality Figures for Mid-April 1961, Showing Radio Disturbance in North Atlantic Area Associated with Severe Magnetic Storm Beginning on April 13. Prepared by CRPL, National Bureau of Standards.

SWI were started in anticipation of geomagnetic disturbance, increased effort by numerous warning agencies may result in improved storm prediction and in discovery of more-effective forecasting techniques for use during this difficult phase of the sunspot cycle.

Major Solar-Terrestrial Events: First Half of 1961

The following is a list of major solar flares; geomagnetic disturbances; and World-wide Geophysical Alerts and SWI during the period January 1-June 30, 1961:

Jan	8 1618	Magnetic storm begins
	10 00xx*	Magnetic storm ends
	19 15xx	Magnetic storm begins
	20 1600	Alert issued (MAGSTORM)**
	19xx	Magnetic storm ends
Feb	3 0908	Magnetic storm begins
	23xx	Magnetic storm ends
	4 1330	Magnetic storm begins
	1600	Alert issued (MAGSTORM)
	7 01xx	Magnetic storm ends
	13 07xx	Magnetic storm begins
	14 01xx	Magnetic storm ends
	16 0044	Magnetic storm begins
	1600	Alert issued (MAGSTORM)
	22 11xx	Magnetic storm ends
Mar	5 21xx	Magnetic storm begins
	6 14xx	Magnetic storm ends
	1600	Alert issued (MAGSTORM)
		SWI starts †
	7 2359	SWI finishes
	9 1327	Magnetic storm begins
	10 13xx	Magnetic storm ends
	1600	Alert issued (MAGSTORM)
	14 0115	Magnetic storm begins
	16 14xx	Magnetic storm ends
	19 04xx	Magnetic storm begins
	1600	Alert issued (MAGSTORM)
	21 00xx	Magnetic storm ends
	26 1009	Class 3 flare; S-SWF††
	27 1505	Magnetic storm begins
	1600	Alert issued (MAGSTORM)
		SWI starts

	28 11xx	Magnetic storm ends
	2359	SWI finishes
	31 1338	Magnetic storm begins
Apr	1 13xx	Magnetic storm ends
	2 20xx	Magnetic storm begins
	3 12xx	Magnetic storm ends
	1600	Alert issued (MAGSTORM)
	9 07xx	Magnetic storm begins
	1600	Alert issued (MAGSTORM)
	17xx	Magnetic storm ends
	13 1452	Severe magnetic storm begins
	14 1600	Alert issued (MAGSTORM)
	16 06xx	Severe magnetic storm ends
	26 1646	Class 3 flare; Slow S-SWF
May	4 2145	Class 3 flare; Slow S-SWF
	6 05xx	Magnetic storm begins
	1600	Alert issued
		PREDICTED SWI starts
	7 16xx	Magnetic storm ends
	2359	PREDICTED SWI finishes
	9 1438	Class 3 flare
	16 01xx	Magnetic storm begins
	17 02xx	Magnetic storm ends
	24 23xx	Magnetic storm begins
	25 1600	Alert issued (MAGSTORM)
	26 04xx	Magnetic storm ends
	31 01xx	Magnetic storm begins
Jun	1 1600	Alert issued (MAGSTORM)
	2 18xx	Magnetic storm ends
	20 18xx	Severe magnetic storm begins
	21 1600	Alert issued (MAGSTORM)
	23 03xx	Severe magnetic storm ends
	29 0011	Magnetic storm begins
	12xx	Magnetic storm ends
	1600	Alert issued (MAGSTORM)

* "xx" indicates gradual beginning or ending of a disturbance, following the hour indicated, such that the precise moment could not be determined.

** No ending times for Alerts are issued; this is left to the discretion of the individual observatories. Capitalized acronyms indicate the kind of Alert issued, i.e., MAGSTORM = magnetic storm; COSRAY = cosmic ray; SOFLARE = solar flare; etc.

† SWI's start at the time the associated Alert is issued (1600 UT) and finish at the end of the day indicated (2359 UT); PREDICTED SWI's are based on the prediction that important geomagnetic and associated activity will begin in a few hours.

†† S-SWF = sudden short-wave fadeout and gradual recovery; Slow S-SWF = slow short-wave fadeout (taking 5-15 minutes) and gradual recovery.

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Annals of the International Geophysical Year

A complete listing of volumes of the IGY *Annals* published or in preparation at that time appeared in *Bulletin No. 28*, October 1959. The following supplementary list brings the earlier list up to date, including correction of several titles:

Vol. IIA, "The International Geophysical Year Meetings," 395 p., 1959.

Vol. IIB, "The International Geophysical Year Meetings," p. 397-709, 1959.

Vol. IX, "The Membership and Programs of the IGY Participating Committees," 307 p., 1959.

Vol. X, "The Fifth Meeting and the Termination of CSAGI," 288 p., 1960.

Vol. XI, In preparation (will include papers presented at the Fifth Meeting of CSAGI other than those on rocket and satellite results, which are published in Vol. XII).

Vol. XII, "First Results of IGY Rocket and Satellite Research," Part 1, 459 p., 1960. Part 2, p. 460-935, 1961.

Vol. XIII, "IGY Ionospheric Tables," 643 p., 1961.

Vol. XIV, "IGY Ionospheric Tables," 545 p., 1961.

Vol. XV, "IGY Ionospheric Tables," 667 p., 1961.

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A monthly survey of plans, activities and findings in geophysics—with emphasis on United States contributions to the International Geophysical Year, International Geophysical Cooperation—1959, and similar international endeavors including the World Magnetic Survey, the Year of the Quiet Sun, the Indian Ocean Expedition, the Antarctic research program, and space exploration and research. Preparation and publication of the Bulletin is supported by the National Science Foundation.

US Antarctic Meteorology during the IGY

Part I: Little America and Amundsen-Scott Stations

The following material is based on a series of reports by US Weather Bureau meteorologists who participated in the IGY meteorological program in the Antarctic. The original reports appeared in various issues of *Weatherwise*, a publication of the American Meteorological Society, and are referenced separately in the Bibliographic Notes of this Bulletin. The most recent report of the series, on IGY meteorology at the USSR Mirny Station, served as the basis for a report in Bulletin No. 52; earlier reports on IGY Antarctic meteorological studies appeared in Bulletin Nos. 15 and 24.

The widespread network of year-round scientific stations established in the Antarctic as part of the IGY program made it possible, for the first time in history, for meteorologists to obtain a broad range of synoptic weather data in that vast, frigid, hitherto little-known portion of the earth's surface. In addition to providing knowledge of the unique weather and climate of Antarctica itself, these studies have provided new insights into atmospheric processes and circulation in general and have improved weather forecasting throughout the Southern Hemisphere. Part I of this report reviews the accomplishments and findings of meteorologists at Little America and

Amundsen-Scott Stations during the IGY period (1957–1958), and Part II, which will appear in *Bulletin No. 54*, reviews the work at Hallett Station, manned jointly by US and New Zealand personnel, Byrd Station, and the Antarctic Weather Central.

Little America IGY Station

The USNC-IGY meteorological observation program at Little America IGY Sta-

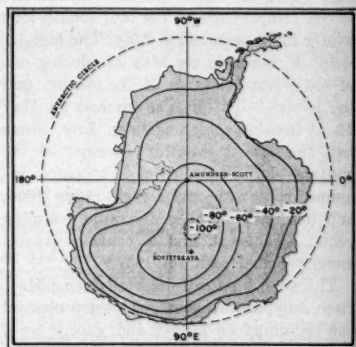


Fig. 1. Isotherms Showing Distribution of Average Surface Temperatures (in °F) for an Antarctic Winter Month—June 1958.

Table 1. *Little America Temperature and Precipitation Data, 1957.*

Month	Temperature (°F)					Precipitation (inches of water equiv- alent)		Snow, Sleet (in inches)		
	Monthly averages	High- est	Dates	Lowest	Dates	Total	Great- est in 24 hrs.	Total	Great- est in 24 hrs.	Dates
Feb	10.3	30	6	-17	19	0.67	0.53	9.5	6.0	23
Mar	-14.7	15	4,20,21	-49	31	0.66	0.25	5.6	1.7	27
Apr	-27.0	10	10	-55	27	0.36	0.13	3.6	1.3	9
May	-23.4	30	11	-63	24	2.31	0.86	22.1	7.6	8-9
June	-11.1	25	15	-51	10	1.50	0.40	15.6	4.0	16
July	-32.0	6	24	-61	10	0.37	0.12	3.7	1.2	20-21
Aug	-30.1	0	29	-56	2,26	0.19	0.06	2.2	0.6	29
Sept	-29.3	-3	14	-51	13	0.32	0.07	2.8	0.7	4-5
Oct	-3.2	29	27	-43	1	1.28	0.31	13.6	3.7	5-6
Nov	9.4	30	30	-16	14	0.58	0.27	5.5	2.8	1-2

tion, Antarctica, began on January 30, 1957, a few hours after the observing personnel had been flown in by helicopter from the *USS Curtiss*, in Kainan Bay.

February at Little America was comparatively mild, making it not too unpleasant to work outside during most of the month. Temperatures fell rapidly during March and April, and the average for April was -27° F. A warming trend followed, during May and June, with the average for June rising to -11.1° F. The highest and lowest temperature of the four-month-long winter night occurred in May. The highest, +30° F, occurred on May 11, during one of the worst blizzards of the winter, and the lowest, -63° F, was reached on May 24. It became colder again in July, which had the lowest monthly average of the winter, -32° F. August and September remained cold, with only a slight rising trend, and not until October did rapid warming begin. (Tables 1 and 2 contain general meteorological data for 1957.)

The worst blizzards occurred during May, June, July, and August, the most prolonged one beginning on May 8 and, except for a few short lulls, continuing until the 15th. On May 8, the temperature read -48° F

and the wind blew from the southeast, continuing from that quadrant almost steadily until the 11th, when it shifted to the north-northeast and increased in speed. The air then became much warmer and more humid, with the temperature rising to +30° F for a short time. This blizzard caused heavy drifting of snow in the camp area, covering the buildings entirely except for the smokestacks protruding through the snow. The strongest blizzard winds struck near the end of August 1957, with 75-mph winds recorded on the 30th.

Before winter was over, the camp was covered by six feet of snow in places and only a few buildings were not completely buried. However, although snowdrifts accumulated quite rapidly in the vicinity of the station during blizzards, the accumulation in level unobstructed areas a mile or more away was probably not greater than 10-15 inches during the year. The greatest snowfalls not associated with blizzards occurred during February and again in October. This snow, of lower density and softer than the hard, packed snow that accumulated during blizzards, was much more difficult to walk on.

Monthly snow accumulation for most of

Table 2. *Little America Wind and Cloud-Cover Data, 1957.*

Month	Wind					Cloud Cover (Number of days)		
	Average hourly speed*	Prevailing direction	Maximum speed**	Direction of max. wind	Date of max. wind	Clear	Partly cloudy	Cloudy
Feb	9.3	SE	—	—	—	1	11	16
Mar	13.5	SE	35	SE	21	4	8	19
Apr	11.7	S	42	N	10	10	7	13
May	15.9	SE	61	NE	14	15	0	16
June	17.3	SE	54	NE	13,14	5	8	17
July	14.5	SE	39	NE	24	10	10	11
Aug	16.2	SE	75	N	30	9	14	8
Sept	12.0	SE	25	NE	14	7	13	10
Oct	17.6	SE	52	NE	7	2	9	20
Nov	11.1	SE	39	N	1	8	5	17
	*knots		**mph					

1957 is shown in Table 1. The accumulation values of 22.1 inches for May and 15.6 inches for June are probably not representative as the measurements were made too near the camp. The snow-stake readings for these months show much less accumulation (Table 3). Because of the rapid build-up of snow cover during February, it was thought that the annual cover would be quite deep. Instead of a continuing rapid pile-up, however, a strong southwesterly wind came up on March 2, and in several hours almost 6 inches of snow had been eroded from the snow cover and blown away, leaving the surface very hard and rough. Where the snow had been compacted by the passage of people or vehicles, it was left several inches above the surrounding surfaces. In general, accumulation during the blizzard months was rather light and it was not until October that the snow surface, as shown by snow-stake readings, again reached its March 1 level.

September was mostly fair and cold, but there was much cloudiness and snowfalls were frequent in October and the first few days of November, restricting aircraft flights and other outside activities. Conditions then improved and there were many sunny days during the remainder of November.

Density measurements of newly-fallen snow were begun in June 1957 and continued until the first part of November, after which no further accumulations occurred that were deep enough to measure. (See Table 4.) After a number of density meas-

Table 3. *Snow Stake Readings at Little America Station.*

Date (1957)	Stake No. 1	Stake No. 2	Stake No. 3	Stake No. 4	Average net accumulation between readings
Mar 1	0	0	0	0	0
Mar 3	-6	-6	-4.5	-6	-5.6
Mar 30	-3	-2	-1	-5	+2.9
Apr 2	-4	-3	-2	-6	-1.0
May 2	-3	-2	-1	-5	+1.0
May 31	-4	+1	-2	-6	0.0
July 1	-1	+1	-2	-6	+0.8
Aug 1	+2	+1	0	-4	+1.8
Aug 31	+1	+1	0	-5	-0.5
Sept 30	+1	+1	0	-5	0.0
Nov 1	+12	+7	+2	-2	+5.5
Nov 30	+14	+6	+3	0	+1.0

(Accumulation is measured in inches.) Total +5.9

Note: The first snow stake was located approximately 500 feet north of the meteorology building and the other three, 200-250 yards apart, formed a straight line running north-northeast from the first. The first three stakes were on an almost level plane while the fourth was on the southern slope of a crevasse valley. The effect of nearness to the camp can be seen on the first two.

Table 4. *Density of Newly Fallen Snow or Snowdrift at Little America Station.*

Date (1957)	Length of core (inches)	Density	Wind range or average velocity (knots) during estimated period of accumulation
June 2	12.0	.208	
June 12	6.5	.077	
June 12	15.5	.178	
July 14	10.0	.269	18-29
July 24	12.0*	.329	25-35
July 30	13.5*	.237	15-25
Aug 1	24.0	.282	23-30
Aug 15	9.0	.145	12-21
Aug 31	24.0**	.437	45
Oct 8	24.0*	.344	32
Oct 23	7.4**	.181	19
Nov 1	24.0	.263	23
Nov 2	17.0	.320	

* Average of two samples

** Average of three samples

Note: Due to the small accumulations of snow on level surfaces, most samples were taken on the leeward side of objects, where sufficient depths accumulated to measure.

urements had been made, it was realized that there might be some correlation between snow density and the speed of the wind while the snow was accumulating. Thereafter, attempts were made to determine the range of wind speeds, or the average speed, during periods when snow was accumulating. This is rather difficult to do as drifts shift from time to time and it is difficult to determine just when a particular drift started to build up. From the few readings obtained, it appears that densities ranged from about 0.1 or less with very light winds (not over 10 knots) and increased by about 0.1 for each 10-knot increase in wind speed up to about 40 or 50 knots. However, not enough readings could be made to determine precisely the nature of this relationship between snow density and wind speed, or whether the temperature might also have some effect on the density.

Frost formation at Little America was very heavy at times, especially during the fall and early spring. Feathery hoar frost, an inch or more thick, occasionally formed on exposed equipment and had to be re-

moved periodically to permit the instruments to function properly.

During periods of high outgoing radiation, the temperature at the snow surface was sometimes 20°-30° F colder than at a height of 50 feet. On one occasion, a difference of 34° F was noted within a small vertical interval.

In general, weather conditions at Little America Station during the IGY were found to be better than expected. Blizzards are the most unpleasant weather phenomena in the Antarctic and create the greatest problems. They often occur unexpectedly and continue for many days, making it almost impossible for men to function outdoors and covering up exposed instruments, buildings, and supplies.

Amundsen-Scott IGY Station

The Amundsen-Scott Station was established at the geographic South Pole, about 9200 feet high (but at a pressure altitude of about 10,500 feet) on the Polar Plateau about 800 miles from Little America Station.

By late April 1957, nearly all meteorological equipment had been installed and was operating at the South Pole Station. The twilight period was over and four months of complete darkness had begun, to be broken only by the appearance of the moon for several days each four weeks. Eight months of winter isolation had begun in mid-February with the departure of the last plane. Temperatures that had been in the -10° to -20° F range in mid-January dropped steadily to the -60° to -80° F range by mid-March and then leveled off. From April through October 1957, the temperature measured at a depth of 30 feet below the snow surface varied by less than 1° F from its mean value of -58.5° F. Table 5 gives weather data for the South Pole Station in 1957.

The meteorological program at Amundsen-Scott Station during this winter period included measurements of snowfall using a gauge mounted on the wind mast, 30 feet

Table 5. Meteorological Data for Amundsen-Scott Station, 1957.

Month	Temperature (°F)					Pressure (mb)					Wind					Cloud cover (Number of Days)		
	Average	Highest	Date	Lowest	Date	Average	Highest	Date	Lowest	Date	Average hourly speed (mph)	Prevailing direction	Maximum Speed (mph)	Direction of Max. wind	Date of Max. wind	Clear	Partly cloudy	Cloudy
Jan 9-31	-18.1	-6.0	11	-29.8	26	687.8	697.3	11	681.0	27	11.3	0°				3	14	6
Feb	-36.8	-18.0	5	-69.2	28	681.0	696.4	16	671.2	28	11.4	0°				11	6	11
Mar	-64.7	-35.0	19	-82.5	29	681.7	695.6	17	664.6	26	13.4	23°E	32	45°E	23, 24	8	12	11
Apr	-69.7	-25.6	6	-89.1	19	681.7	692.9	30	669.8	14	17.3	23°E	39	23°E	5	17	10	3
May	-68.3	-30.1	15	-100.4	12	684.2	713.2	27	667.5	19	17.2	23°E	54	23°E	25	19	8	4
June	-69.6	-42.3	12	-97.0	18	685.7	701.3	15	671.5	12	19.1	45°E	38	23°E	10, 25	27	3	0
July	-77.5	-40.7	3	-98.8	29	673.2	683.0	16	657.3	30	17.4	23°E	43	23°E	3, 4, 5	23	6	2
Aug	-72.7	-45.4	4	-99.7	27	682.0	703.0	6	657.3	1	18.0	23°E	38	23°E	1	20	8	3
Sept	-80.1	-57.7	30	-102.1	18	677.3	684.7	7	663.1	2	14.7	90°E	42	45°E	29	19	8	3
Oct	-62.9	-45.4	18	-86.1	3	677.3	682.4	7	670.2	20	15.8	23°E	39	23°E	12	12	16	3
Nov	-34.4	-2.2	22	-54.6	1	688.5	700.3	23	677.3	7	10.9	23°E	32	23°E	23	18	10	2
Dec	-13.4	-2.0	15	-21.5	3	693.5	704.7	18	681.0	30	8.2	23°E	22	23°E	17	14	10	7
Year	-55.7					682.8					14.5							

above the snow surface. This was an attempt to obtain more accurate measurements of falling snow, since records of the amount collected on the surface are always biased by an unknown amount of drifting snow. Table 6 shows precipitation for the winter of 1957, in terms of both solid amounts of snow (S.A.) and of water equivalents (W.E.), for gauges on the ground and on the 30-foot mast. Replicas of falling snow crystals were also made when conditions permitted. The types of crystals most frequently observed were bullets (rod-like forms) and skeleton plates (flat, branching, star-shaped forms).

Interesting features of the Antarctic

stratosphere are the gradual cooling from February into August and the very rapid warming in October-November. In 1957, the cooling trend culminated in minimum stratospheric temperatures of -90° to -93° C, measured at altitudes of about 18-20 km in late July and early August.

Early in the year, the wind was rarely calm and, surprisingly, as winter approached the average wind speed increased. In the 720 hourly observations made during June, for example, no wind speeds of less than 6 knots or of more than 30 knots were recorded. June was the windiest month in the sense that it had the highest average speed (19.1 mph) but it was a typical win-

Table 6. Precipitation at the South Pole Station, Winter 1957.

Location of gauge	July		August		September		October	
	S.A.*	W.E.**	S.A.	W.E.	S.A.	W.E.	S.A.	W.E.
Surface	6.9"	1.45"	10.5"	1.50"	1.6"	0.36"	23.5"	6.67"
30 feet above surface	0.5"	0.09"	1.4"	0.12"	0.3"	0.04"	0.35"	0.04"

* Solid amounts

** Water equivalents

Table 7. *Winds at Amundsen-Scott Station, June 1957.*

	Speed (knots)								Nr. hours	Frequency (% of time)	Average speed
	Calm	1-5	6-10	11-15	16-20	21-25	26-30	>30			
Calm	0	—	—	—	—	—	—	—	0	0	—
N (0°)	—	0	0	2	1	0	0	0	3	0.4	15.0
NNE (22°E)	—	0	3	26	63	63	6	0	149	20.7	19.4
NE (45°E)	—	0	3	63	121	56	2	0	245	34.0	17.9
ENE (77°E)	—	0	12	66	61	8	0	0	147	20.4	15.4
E (90°E)	—	0	13	115	20	0	0	0	148	20.6	13.5
ESE (112°E)	—	0	2	21	5	0	0	0	28	3.9	13.8
SE-NNW	—	0	0	0	0	0	0	0	0	0	—
Total hrs.	0	0	31	293	271	117	8	0	720	Monthly average speed	16.6
Frequency (% of time)	0	0	4.3	40.7	37.6	16.3	1.1	0			

ter month as far as the distributions of speed and direction were concerned. (See Table 7.)

Even periods of extreme cold were frequently accompanied by winds of moderate speed. The most severe day in this respect was July 29, when the average temperature was -94°F , with a high of -90° and a low of -99° , yet the average hourly wind speed for the day was 16.4 knots. Under such conditions, an exposed nose or cheek can be frozen in seconds if the mistake is made of facing into the wind.

The wind observations also showed that nearly all of the coldest days occurred when the wind blew from 90°E . This implied the existence of higher terrain and a colder climate in that direction, the advective effects of which were not entirely compensated by the adiabatic heating of the descending air. As indicated in Figure 1, a map of the isotherms of average surface temperature for June 1958, the "cold pole" of Antarctica probably is situated somewhere between the US South Pole Station and the USSR Sovietskaya Station.

Meteorological Applications of Explorer VII Infrared Radiation Measurements

The following material is based on a more-detailed report, by Lt. Col. Melvin Weinstein, USAF Air Weather Service, and Verner E. Suomi, Department of Meteorology, University of Wisconsin, which appears in the US Weather Bureau's Monthly Weather Review, November 1961.

The radiation-balance experiment aboard IGY satellite Explorer VII (1959 Iota) was designed to measure solar, reflected, and terrestrial radiation currents in order to determine the radiant heat flow to and from

the earth and, ultimately, to obtain a clearer understanding of the driving force behind the circulation of the atmosphere. A report in *Bulletin No. 52* describes the background, instrumentation, and techniques of the Explorer VII infrared radiation experiment and presents earlier results of analyses of the data obtained, which show large-scale radiation patterns around the earth and indicate an apparent relationship between these radiation patterns and large-scale surface weather patterns.

In the continuing work on which the pres-

ent report is based, these initial studies were carried further by comparing Explorer VII maps of long-wave radiation loss with composite nephanalyses (cloud-cover analyses) as well as with frontal analyses, and by plotting on a single map the locations and patterns of movement of radiation centers and lower-atmosphere pressure centers.

Results of these continuing studies definitely confirm a correspondence between radiation centers and near-surface low- and high-pressure centers with respect to location, 24-hour intensifications and movements, and the conformity of these movements to the geostrophic flow at the 500-milibar level (about 19,000 feet). (Geostrophic flow is horizontal frictionless flow of air in which the apparent force arising from the earth's rotation exactly balances the horizontal force resulting from pressure differences.) Potential weather-analysis and forecasting applications are also discussed.

Analysis Procedure

Because the spherical infrared sensor integrates the radiation over a large segment of the earth, composite radiation maps could be drawn using data from successive satellite passes, even though the passes were about 1 hour and 40 minutes apart. Isolangleys, lines of equal long-wave radiation loss expressed in langleys per minute $\times 10^{-3}$ are shown on the radiation maps (1 langley, ly, equals 1 gram-calorie/cm²).

As the radiation maps are not synoptic, composite surface-frontal and nephanalysis maps coinciding as closely as possible with the times of the radiation observations were constructed on the basis of National Weather Center analyses. The composite nephanalyses separate overcast (including fog and obscured-sky), broken, and clear-to-scattered areas. The lack of data over many oceanic and tropical areas limits both types of composite analysis.

First the radiation maps were drawn as completely and independently as possible, and then the composite nephanalyses were

drawn. In areas north of 35°–40° N, where data were sufficient for independent radiation analyses and nephanalyses, the close relationship between the two was apparent. Hence, the nephanalyses, if available, were used to supplement the radiation analyses for local areas where radiation data were sparse. Despite the limitations of this method, it was used in these early radiation maps in order to permit as much study as possible of their potential value. With increased observational density completely independent radiation maps can be drawn.

It is interesting also to note that in those large portions of the oceans and tropics where no surface observations are available for nephanalyses, the major source of data was the satellite's radiation observations. However, because of the large gaps between orbital paths in the tropics, interpolation in drawing isolangleys is difficult. Here, 24-hour continuity in radiation observations would prove invaluable.

Characteristics of Radiation Maps

That clouds dominate the formation of the radiation pattern is apparent when radiation analyses (Fig. 2) are compared with associated nephanalyses (Fig. 3) for areas north of 40° N. Since the extensive mid-latitude cloud systems of variable vertical development are caused by surface low-pressure centers and fronts, the resulting radiation-map patterns also reflect these sources. Where a surface low or front is most intense, the cloud tops are higher and colder and the amount of outgoing long-wave radiation is smaller. As the cloud tops become lower, the radiating temperature rises and the amount of radiation measured by the satellite sensor increases. On the radiation map, this is seen as a radiation low over the area of maximum cloud development, with higher isolangley values over the area of lower cloud tops. The highest radiation readings are found over the central and eastern sections of surface highs, where clear to scattered-cloud conditions prevail.

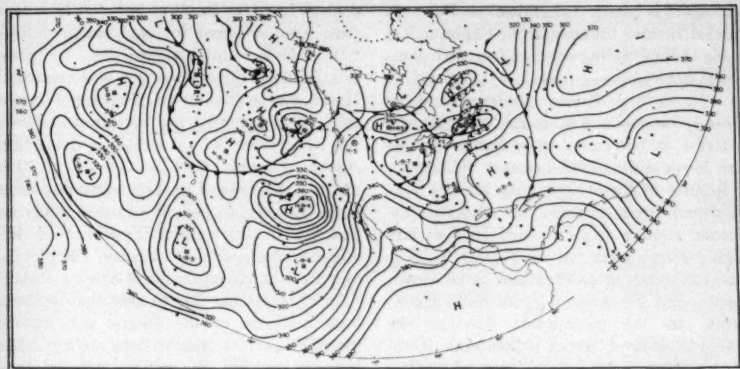


Fig. 2. Radiation Analysis for Part of Northern Hemisphere, December 1, 1959. Isolangleys show long-wave radiation loss in $\text{ly/min} \times 10^{-4}$. Surface-pressure centers (circles marked H or L, for high or low, and numbered) and surface fronts are composite to satellite passage time; radiation centers (squares) are similarly marked but include "R" in designation; dots show observation points and orbital path of satellite.

From the above relationships, one would expect to find that, in mid-latitudes, the center of the radiation low is east of the surface-low center and the center of the radiation high is east of the surface-high center; this relationship does, in fact, occur in 24 of the 25 cases for which data are available (see Figs. 4 and 5).

In an example of this relationship seen on the maps for December 3, 1959, a radiation low over the Pacific Ocean is located southeast of a surface low and the associated occlusion. Moreover, the orientation of the radiation low and trough (elongated area of low radiation, which may include one or more low centers) parallels the occlusion and the area of maximum frontal intensity, and the radiation pattern's spiral-like northwestward extension resembles Tiros cloud photographs of occlusions.

In addition to indicating frontal location, the radiation trough also indicates frontal intensity and 24-hour frontal changes—the former by the sharpness and strength of isolangle gradient and the latter by the 24-hour change in these factors. An example is the cold front beginning in northwestern

Canada from the remnants of an old occlusion and extending southwestward into the Pacific, on December 1, 1959 (Fig. 2). The radiation map correctly indicates that the front is stronger in the region where its clouds produce radiation low L-R-4 and the sharp radiation trough to its southwest; weaker through the area where radiation high H-R-3 is associated with clear to scattered-cloud conditions (Fig. 3); and again more intense as it changes to a warm front leading into the unstable wave of surface pressure low L-1, where the radiation trough strengthens toward L-R-1. A weakening of this radiation trough off the Pacific coast on December 2 reflects decreased activity of the surface cold front.

The entire radiation trough pattern from L-R-4 to L-R-1 and then southwestward resembles a cyclone "family," and, in fact, is the radiation-map reflection of one. The development of family "member" L-1 from an unstable wave to an occlusion can be followed on succeeding radiation maps.

Arrows representing the pattern and location of maximum winds on the US Weather Bureau 0000 GMT 300-mb maps

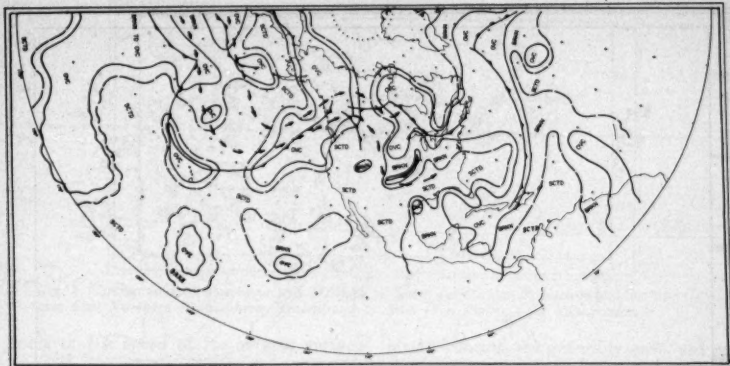


Fig. 3. Composite Nephanalysis for Part of Northern Hemisphere, December 1, 1959, based on 0000, 0600, and 1200 GMT Surface Maps. Overcast areas (OVC) bounded by solid lines; dash lines separate clear to scattered-cloud (SCTD) areas from broken-cloud areas (BRKN: 5/8-7/8 cloud cover); wavy lines used where cloud-area edge unknown owing to insufficient data; arrows show location and direction of maximum winds, from 300-mb chart for 0000 GMT.

(about 30,000 feet) are plotted on the nephanalyses. On December 1, 1959, (Fig. 3), the maximum upper-wind and frontal patterns conformed to the pattern shown by other investigators for the relationship of the jet stream to a cyclone family. The patterns of radiation lows and troughs are seen to show the same relationship to the jet stream as do the surface lows and the fronts of the cyclone family.

While radiation lows usually reflect surface lows or fronts, they can also be caused by cold or snow-covered surfaces or by extended sheets of high clouds. Both of these sources may generally be distinguishable by radiation-map analysis and by continuity over several successive radiation maps. No snow surfaces are indicated in the series of maps used in this study, but it seems very likely that extended sheets of high clouds caused those tropical radiation lows that are not related to identifiable synoptic features. (Such large areas of high clouds in the tropics have been reported by a number of other investigators.) It is felt, also, that if sufficient radiation observations are made above an easterly wave, a radia-

tion minimum would be seen over the high clouds in the convergence area. Available synoptic data do not indicate any easterly waves for these dates, however.

24-Hour Intensity Changes

Increases in size, vertical development, and meridional expansion of cloud patterns during the intensification of surface or upper-air lows are reflected in the radiation patterns. In the present study, changes in value of radiation centers reflect the diurnal intensity changes of their surface counterparts for five of eight high centers and for four of six low centers (see Figs. 4 and 5). Reasons for failure to detect this coincidence for the remaining three highs and two lows are difficult to determine, but it is possible that the pressure changes may have been too small to result in changes in clouds and in radiation intensity, or that the clouds may already have been at maximum height. From the limited examples available, it can be stated that in all of the four cases for which the 24-hour change in magnitude of the surface low was greater

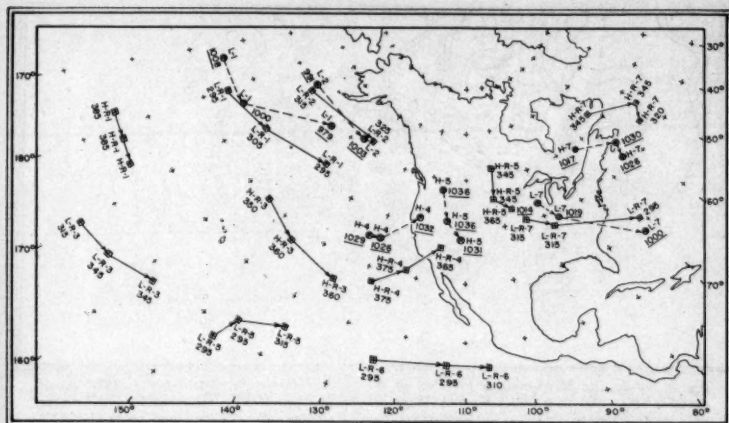


Fig. 4. Surface- and Radiation-Center Continuity, December 1-3, 1959. Relationships between positions and motions (solid arrows) of radiation centers and positions and motions (dashed arrows) of surface-pressure centers are shown at 24-hour intervals. Radiation values in $\text{ly/min} \times 10^{-4}$; surface pressures (underlined) in mb.

than 10 mb, there was a corresponding change in radiation-low intensity.

Intensification of surface centers is also shown by 24-hour shifts in the relative positions of corresponding radiation centers. Radiation low L-R-7, for example, moved from southeast to north-northeast of its corresponding intensifying surface low from December 2 to 3, 1959 (Fig. 4). In another example, limited data for the Pacific indicate that L-R-1 was located east-southeast of surface low L-1 on December 1, moved to the east-northeast of L-1 on December 2, and then to the southeast of this surface low after occlusion took place. On both dates, L-1 deepened (decreased in pressure).

With an intensifying system such as L-1 moving northeastward, some northward motion of the radiation low relative to the surface low (reflecting the movement of highest clouds) would normally be expected. However, on this occasion, the radiation low and trough were apparently in the region of most intense convergence and vertical motion, just ahead of the surface po-

sition of the occlusion. It was also noted for the few available examples of surface lows that were either weakening or not changing, that the associated radiation lows retained approximately the same positions relative to the surface lows. L-2 and L-4 and their companion radiation lows are good examples (see Figs. 4 and 5).

Another indication of surface-low intensification based on radiation-map data alone was an observed change in orientation of radiation-low patterns from east-west to north-south coupled with decreases in magnitude of the radiation center. The reverse applied to weakening systems.

24-Hour Motion and 500-mb Geostrophic Flow

Figures 4 and 5 show a possibly useful relationship between the 24-hour movements of mid-latitude surface lows and highs and the movement of associated radiation lows and highs. The 24-hour motions of six out of seven radiation highs remained within about 20° of the direction of motion and 10

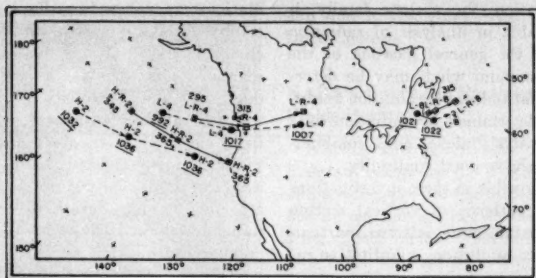


Fig. 5. Comparison of Positions and Motions of some Additional Radiation and Surface Centers over Northern Hemisphere, December 1-3, 1959. (See Figure 4 for explanation.)

knots of the speed of the related surface systems. For the seventh, comparison is complicated by absorption of the surface high by another high. Nevertheless, the 24-hour movements of all seven radiation lows followed the movements of their associated surface lows within these limits.

A positive relationship was found between the 24-hour motion of radiation-low centers and the average 500-mb geostrophic wind velocity over their areas of motion. Using computations made from contour spacings on the National Weather Analysis Center 500-mb maps for December 1-4, 1959, it was found that the motions of four of seven radiation highs were within 20° of the direction and 40-60% of the speed of the related 500-mb geostrophic wind. The motions of radiation lows show even better correlation, with six of the seven remaining within these limits.

The above results indicate that the motion of the center of a radiation low could be used to determine the 500-mb flow pattern and the approximate location of the corresponding surface-low center, its movement, and possible changes in its intensity.

Cirrus clouds causing the tropical radiation lows were probably at altitudes between 12 and 16 kilometers. Although the 500- and 300-mb analyses extend only to latitudes of 15° - 20° N, the contour pattern indicates that the flow of the westerlies continued farther south at these and higher

levels, causing the generally eastward motion of radiation centers H-R-1, L-R-5, and L-R-6 (Fig. 4). L-R-3 could have been under the influence of the equatorial westerlies which, according to previous studies can extend to a height of 16 km. These subtropical centers also showed good continuity—i.e., smoothness of change of character with time and distance.

Summary and Conclusions

The long-wave radiation measurements made by the relatively simple, omnidirectional, white sensor installed aboard Explorer VII can be used to produce radiation maps contoured in ly/min. Analysis techniques are similar to those now used for surface and upper-air maps. In mid-latitudes, where adequate data exist for analysis, the radiation pattern was found to be consistent with the nephanalysis pattern and with synoptic features.

The radiation map appears to offer many aids to weather analysis and forecasting, particularly for areas of sparse data. The best results are obtained for mid-latitudes, for which radiation-low centers approximate the locations, motions, and intensity changes of corresponding surface-low centers. In addition, in limited areas where the direction of motion of a radiation low can be determined, the upper-air pattern and 500-mb winds may be approximated. A special

synoptic situation, the cyclone family, is also recognizable in analysis of radiation patterns, and the general location of the associated maximum winds may be determined. In all latitudes, the radiation analysis, whether determined by radiation data alone, nephanalysis alone, or a combination of both, shows good continuity.

It may be possible in these investigations to determine patterns of vertical motion from the radiation-map patterns, particularly if the low-resolution, quantitative ra-

diation-map values from Explorer VII are combined with high-resolution, qualitative cloud pictures from a Tiros satellite. (Research on this technique is now being conducted at the University of Wisconsin.)

If two satellites were used to make radiation measurements, observation density would be increased and the resulting maps would be more nearly synoptic; polar-orbit satellites having data-storage capability could give global coverage—depending on number and locations of read-out stations.

Energetic-Particles Satellite: Explorer XII

Explorer XII, instrumented to measure energetic particles and magnetic fields to distances greater than 10 earth radii, was launched from Cape Canaveral, Florida, at 11:21 pm EDT, August 15, 1961. (See Figure 6.) The satellite entered a highly eccentric orbit, as planned, with apogee at a distance from the earth of approximately 77,340 kilometers (47,950 statute miles); perigee at about 294 km (182 statute miles); orbital inclination of 33° with respect to the equator; and orbital period of 26 hours 25 minutes.

Explorer XII is the first of several energetic-particles satellites designed specifically to make repeated observations of the solar wind; interplanetary magnetic fields; distant regions of the earth's magnetic field; and the charged-particle population of interplanetary space and of auroral radiation and the trapped-radiation regions near the earth (the Van Allen Radiation Belts). The Van Allen belts, which surround the earth between north and south latitudes of 70° and between distances of about 1000 and 50,000 km are traversed twice during each orbit of the satellite. (See Figure 7.)

With its highly eccentric orbit, Explorer XII provides a unique opportunity to study the physics of fields and energetic particles in space. At apogee, the satellite is essentially in interplanetary space beyond the earth's effective magnetic field; as it moves away from apogee, the satellite passes through the trapped radiation regions; and at perigee it is located below these regions.

The experiments aboard Explorer XII have been carefully selected to cover the particle spectra from energies of a few eV to 10^9 eV. Simultaneous magnetic-field measurements extending to a lower limit of several gammas will also be made, and a solar plasma probe has been provided.

NASA's Goddard Space Flight Center has the major responsibility for the Explorer XII energetic-particles satellite, for its integration with the Delta launch vehicle, and for tracking and data reduction. NASA Project Manager for Explorer XII is Paul Butler, of Goddard, and Frank B. McDonald, also of Goddard, is Scientific Advisor. John E. Naugle is chief of NASA's Energetic Particles Program.

The Explorer XII cosmic-ray, ion-electron-detector, and solar-cell experiments



Fig. 6. Explorer XII Energetic-Particles Satellite (1961 Upsilon). NASA drawing.

are being conducted by the Goddard Space Flight Center under the direction, respectively, of F. B. McDonald, L. R. Davis, and G. W. Longanecker. The proton-analyzer experiment, is conducted by NASA's Ames Research Center, under the direction of Michael Bader. Lawrence Cahill directs the magnetometer experiment of the University of New Hampshire, and B. J. O'Brien directs the State University of Iowa experiment to measure trapped and solar particles and cosmic rays.

Approximately 50 private contractors also participated in the Explorer XII project and are contributing to NASA's Energetic Particles Program.

As soon as it was affirmed that Explorer XII had entered a stable orbit, a message containing basic information about payload characteristics, experimental aims and instrumentation, and orbital details was sent to COSPAR for distribution to participating national organizations. Scientific information obtained by the satellite is also being sent to COSPAR for similar distribu-

tion and is being deposited in the World Data Centers.

NASA's Energetic Particles and Fields Program

NASA's Energetic Particles and Fields Program is concerned with rocket, satellite, and space-probe studies of charged particles having energies greater than a few electron volts. These include solar and galactic cosmic rays, magnetically trapped radiation in the vicinity of the earth and planets, and interplanetary plasmas. The interaction between charged particles and magnetic fields in space is such that both must be studied simultaneously on the same spacecraft. In addition to mapping fields and particle fluxes in space, it is hoped that the data obtained in these studies will provide answers of fundamental questions concerning the origin and method of acceleration of cosmic rays, the nature of the interplanetary magnetic field, and the mechanism responsible for planetary magnetic fields.

It is also necessary, in order to understand certain of these phenomena, to obtain simultaneous measurements at widely separated points in the solar system. Particle and field experiments are therefore planned for deep-space probes such as Ranger and Mariner.

Certain of these phenomena are related to the 11-year solar cycle and must be monitored carefully through an entire cycle. At present, we are in a transition period between the high solar activity of 1957-58 (the IGY period) and the solar minimum expected to occur in 1964-65 (the planned IQSY period; see *Bulletin No. 48*).

Specific areas of investigation of NASA's energetic-particles program are as follows:

Cosmic Radiation: Primary cosmic radiation consists of a continuous flux of protons (H^+), alpha particles (He^{++}), and the nuclei of heavier atoms, and ranges in energy from a few million electron volts to about 10^{19} ev, or more. The flux varies by a factor of almost two over the 11-year

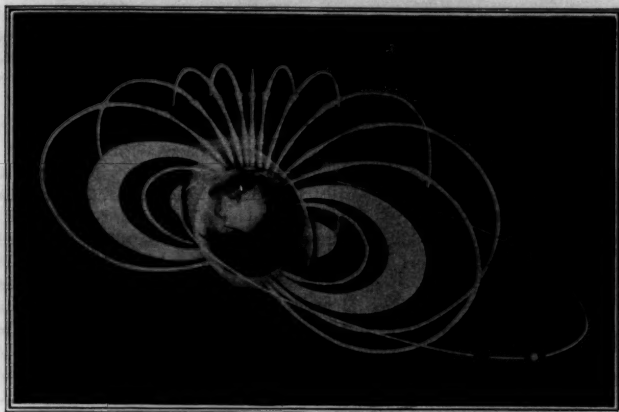


Fig. 7. Schematic Representation of Explorer XII Orbit. Position of orbit relative to Van Allen Radiation Belts, geomagnetic field, and earth's atmosphere are shown. NASA drawing.

solar cycle, occasionally decreasing sharply for a few days after a solar flare—the so-called Forbush decrease. The origin of cosmic-ray particles, the mechanism by which they are accelerated to very high energies, their association with the 11-year solar cycle, and the Forbush modulation of the flux and energy spectrum are some of the problems that have shaped this part of the experimental program.

Very-high-energy primary cosmic rays are galactic, or in some cases extragalactic, in origin and pour toward the earth continuously and from all directions. The lower-energy solar cosmic radiation is detected as proton bombardments of the earth's polar regions following solar flares and lasting from a few hours to several days. For a better understanding of solar cosmic rays, following areas required experimental and theoretical investigation: (i) composition, flux, and energy spectra of the particles, and the variations of these quantities with time and position during a solar-cosmic-ray event; (ii) the nature of the solar mechanism that accelerates these particles to high energies and the re-

lation between this mechanism and other solar phenomena; (iii) the trajectories of the particles and their distribution in space during an event; (iv) variation of the frequency and intensity of solar-cosmic-ray events over an entire 11-year solar cycle; and (v) radiation levels in space.

Auroral and Geomagnetically-Trapped Radiation: The geomagnetically trapped and auroral radiation are both associated with the earth's great radiation belts. The Van Allen Radiation Belts consist of two major regions—an inner region, stable with time and characterized by a high density of protons with energies ranging from a few Mev to about 700 Mev, and an outer region, varying with time and consisting of particles with energies of less than one Mev. It is believed that a mechanism in the vicinity of the earth accelerates the particles trapped in the belts. In addition, measurements made during the IGY have shown that both low-energy protons and electrons are associated with auroras, the major part of the incident energy being carried by the electrons.

Some of the primary questions in this

area concern: (i) origins of the radiation in various regions of the Van Allen belts; (ii) lifetimes and trajectories of the trapped and auroral particles; (iii) nature of the local accelerating mechanism; (iv) relation between the trapped and auroral radiation; (v) effects of this radiation on the earth's atmosphere and ionosphere; and (vi) the possible existence and nature of similar belts around the other planets and the moon.

Interplanetary Plasma: The energetic-particles program is investigating fundamental questions about the interplanetary plasma relating to (i) composition of the particles; (ii) their number-density, direction flux, and energy spectra; (iii) relation of these properties to the magnetic field at any point in time and space; and (iv) time variations, ranging from short periods (hydromagnetic waves) to periods of 11 years (solar cycle).

Magnetic Fields: The magnetic-field portion of this NASA program seeks to measure the magnetic fields of the sun, the planets and natural satellites of the solar system, and interplanetary space. Experiments are carried out in conjunction with scientific investigations of the physical processes causing the fields and their changes with time.

Major specific objectives are (i) to survey the entire geomagnetic field in as great detail as possible; (ii) to investigate the sources (presumably ionospheric) of electric current systems giving rise to such ground-observed phenomena as the diurnal magnetic variations (solar and luni-solar), of the more-pronounced variations caused by the equatorial electrojet (see *Bulletin No. 25*), and of magnetic-storm changes, particularly the polar disturbances; (iii) to study the character of the distant portions of the geomagnetic field, including rapid fluctuations possibly related to hydromagnetic waves in the exospheric plasma (Evidence from previous satellites and probes suggested the existence of a ring current [see *Bulletin No. 36*], but uncertainties regarding interpretation of data has made

necessary further investigations, in which satellites in eccentric orbits can contribute especially useful information.); (iv) to study the interplanetary magnetic field and its fluctuations, which, presumably, result from the "frozen" fields of plasma clouds ejected from the sun and from hydromagnetic waves traveling through the interplanetary medium; and (v) to study possible magnetic fields of our moon, of Mars and Venus, and, later, of other planets by planned near-misses with space probes, providing information about the existence of such fields and about their character, their approximate magnitude, and the orientation of their poles.

Previous Investigations: Several important experiments have already been completed in the energetic-particles and fields program. Explorer VI, launched August 27, 1959, detected a ring of electrical current circling the earth and mapped the Van Allen Radiation Belts; Vanguard III, launched September 18, 1959, made a large number of accurate magnetic-field measurements in space near the earth (see *Bulletin No. 46*); Explorer VII, launched October 13, 1959, collected data on energetic particles in the Van Allen belts; Pioneer V, launched March 11, 1960, supplied additional data on energetic particles and their distribution as well as on the interplanetary magnetic field (see *Bulletin No. 36*); and Explorer X measured plasmas and magnetic fields in space near the earth (see *Bulletin No. 48*).

Explorer XII Payload Characteristics

The 83-pound Explorer XII satellite carries 10 particle-detecting systems and associated electronics in a 1.578-cubic-foot, octagonal, walled compartment of nylon-honeycomb and fiberglass, with an aluminum cover .02-inch thick. The compartment is 5½ inches high and its side-to-side diameter is 26 5/32 inches. A magnetometer package is located forward of the platform on a 32-inch boom, in order to reduce mag-

netic effects from the electronics and instruments. The transmitter is in the base of the payload.

Four 13.68×20.18 -inch paddles containing a total of 5600 solar cells extend from the main structure, giving the satellite an over-all diameter of about five feet when in orbit. The paddles, oriented to allow a uniform solar-cell-projection area at any payload-solar attitude, were initially folded along the last-stage rocket and erected during flight. After last stage burnout, a de-spin device reduced the satellite's roll-rate to approximately 31 rpm and erection of the paddles further reduced it to approximately 18 rpm. Thirteen silver-cadmium storage batteries, recharged by the solar cells, provide 16 watts of power.

Experiments Aboard Explorer XII

The experimental instrumentation aboard Explorer XII is designed to measure particle energies over a range wide enough to include the expected nominal values of the solar wind, the Van Allen Radiation Belts, solar protons, and galactic cosmic rays. Figure 8 shows graphically the energy ranges covered by Explorer XII's detectors, the energy ranges of the various types of particles measured, and the intensity areas in which direct determinations can be made by each detector.

Proton Analyzer: This experiment is designed to measure the low-energy proton flux and spectrum at distances of one quarter to 10 earth radii (about 1500-65,000 km). These particles are believed to make up 85% of the energized particles in space. Data obtained will add to our knowledge of proton concentrations in the solar winds caused by solar flares, and will be useful for correlating particle activity in space and in the Van Allen Radiation Belts with solar activity.

Many scientists consider the interplanetary plasma as simply a continuation of the sun's atmosphere, or corona, consisting mostly of protons and electrons. Others be-

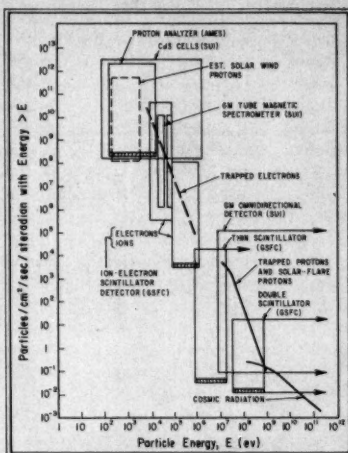


Fig. 8. Energy-Spectra Ranges of Explorer XII Detectors and of Particles being Measured. Curves represent expected nominal values, as a function of particle kinetic energy, of the solar wind (dashed rectangle, top left); Van Allen region electrons (dashed line); Van Allen region protons and solar protons (upper solid line); and cosmic rays (lower solid line). Solid rectangular areas represent energy and intensity intervals covered by Explorer XII instrumentation. All detectors have large dynamic ranges to allow for expected fluctuations; cross-hatched areas indicate intensity intervals in which particle-energy spectra can be determined directly.

lieve that a solar wind—ionized atoms of gas, primarily hydrogen, moving at velocities of several hundred to a thousand miles a second—constantly streams away from the sun. Recent measurements of Explorer X tend to confirm the existence of the solar wind.

The plasma probe in Explorer XII, designed and built at Ames, records the presence of particles as a function of their energy, in the range 200 ev–20 kev, which corresponds to the expected 200- to 2000-km/sec velocity range. Charged particles enter the analyzer through a slit in the sat-

elliptic skin opening into a curving tunnel. The two sides of the tunnel are metal plates carrying static electric charges, one negative and the other positive. A charged particle is attracted by one plate and repelled by the other, and so follows the curved path down the tunnel. If it is moving either too slowly or too rapidly it runs into one wall or the other, but if it is within the right velocity range, it makes its way to the particle counter at the end of the tunnel. Thus, all particles moving in a particular direction and within the desired velocity range are detected. At fixed intervals the range of energies is changed.

Magnetic Fields: This experiment measures the magnitude and direction of the earth's magnetic field at distances between 3 and 10 earth radii (approximately 20,000-65,000 km). It is also investigating the possible termination of the geomagnetic field in the vicinity of 10 earth radii. The data gathered will determine whether postulated current systems and magnetic disturbances actually exist in extraterrestrial space, particularly in association with solar events and changes in particle intensities.

Several satellite and space-probe measurements have already provided some information about the geomagnetic field and the interplanetary magnetic field between the earth and the moon, where these fields interact to form a complicated boundary.

The flux-gate magnetometer used for these Explorer XII measurements is a three-core device. Each of three orthogonal sensors measures a magnetic field element along that sensor. The output voltages of the sensors are then combined to form the total-magnetic-field vector. The range of measurement is from a few gammas to 1000 gammas.

Trapped-Particle Radiation: The fluxes, energies, and spatial and temporal dependence characteristics of particle radiation—geomagnetically trapped, solar, and cosmic ray—are measured over the entire spacecraft orbit in this experiment.

Instrumentation consists of four Geiger

counters and three cadmium-sulphide cells. One counter detects protons with energies above 20 Mev and electrons above 2 Mev, arriving from all directions. The three other Geiger tubes make up an electron spectrometer, one detecting electrons with energies between about 40 and 55 kev, another monitoring penetrating radiations (protons above 50 Mev and electrons above 10 Mev), and the last one measuring electrons between 90 and 100 kev.

The cadmium-sulphide cells are solid-state, semi-conductor devices that change their electrical resistance in proportion to the rate of bombardment by charged particles. One cadmium-sulphide cell measures the total energy flux of both protons and electrons down to energies of 100 ev, or less. Another has a magnet that deflects electrons below several hundred kev, thus measuring only the low-energy protons. The third cadmium-sulphide cell is fitted with a transparent shield so that accurate corrections may be made for the effects of light (earthlight or sunlight) striking the other two cells.

Cosmic Rays: The Explorer XII cosmic-ray monitoring equipment permits study of both the production and modulation of cosmic rays with the same set of experiments. Charge and energy spectra of the cosmic radiation are measured as a function of distance from the earth, time, and direction.

The cosmic-ray package consists of three basic detection units: a double scintillation-counter telescope, a single crystal detector, and a Geiger-Mueller telescope. The first detector measures the total cosmic-ray flux; the flux of fast protons with energies greater than 700 Mev; the differential energy spectrum of protons in the region 70-750 Mev; and the low-energy portion of the alpha-particle differential-energy spectrum.

In order to extend the proton energy-spectrum data down to 1 Mev, a thin cesium-iodide scintillation counter is used as the second detection unit. The pulse-height distribution of incident particles in the energy range 100 kev-20 Mev is ob-

tained. This unit also provides information on low-energy solar gamma rays.

The third unit, the Geiger-Mueller telescope, consists of two Geiger counters that serve as cosmic-ray monitors, furnishing a check on the information received from the scintillation-counter units.

Ion-Electron Detector: This detector measures particle fluxes, types, and energies—as a function of direction, time, and position—below, in, and above the Van Allen Radiation Belts. The detector is most sensitive to the low-energy particles, which, although they have not yet been measured directly, appear to exist in both the inner and outer radiation belts.

The ion-electron scintillation detector consists of a powder phosphor on a photo-multiplier tube located behind a stepping absorber wheel. Ion counting rates for two trigger levels are registered with respect to seven absorber thicknesses, from which ion types and energy spectra can be deduced. The electron energy flux is also obtained, and electron energy spectra can be deduced by comparing the responses from six absorber thicknesses. Total energy flux is obtained for seven absorber thicknesses by measuring the photo-multiplier current.

The ion detector measures protons in the energy range 0.1 kev-1 Mev; the electron detector records within the energy range 10-100 kev; and the total-energy-flux detector functions over the energy range of 30 kev to 1 Mev for protons and 10-100 kev for electrons.

Solar Cells: Deterioration of solar cells from direct exposure to the Van Allen radiation is investigated in this experiment. Four strips of silicon solar cells, with 10 cells per strip, are mounted on the surface of the spacecraft. One strip is unprotected while the remaining three are protected by 3-, 20-, and 60-mil-thick glass filters. During the lifetime of the spacecraft, the effectiveness of the different thicknesses of glass in preventing deterioration of the cells will be compared.

Optical-Aspect Sensor: Explorer XII

carries an optical-aspect sensor to determine its orientation in space as a function of time. Six photo-diodes give the sun's elevation with respect to the spin axis of the satellite. The photo-diodes are placed behind a light mask so that each sees only the portion of the light mask directly in front of it, and a digital computer having memory and logic capabilities, determines the time at which a particular photo-diode sees the sun.

Telemetry

A 2-watt, 136.02-megacycle transmitter operates continuously in Explorer XII. Because of its highly eccentric orbit, the satellite is visible for approximately 23 hours at receiving stations on the apogee side of the earth. Three stations, at Woomera, Australia, Santiago, Chile, and Johannesburg, South Africa, are spaced in longitude such that, together, they can record the telemetry signal for 90% of the time. Initial plans were to record telemetry continuously for one month and periodically thereafter as required.

Tracking

Tracking Explorer XII on the apogee side of the orbit are the existing Minitrack stations at Woomera; Johannesburg; Santiago; Antofagasta, Chile; and Lima, Peru. The rapid passes of the satellite through perigee are tracked as the satellite crosses existing Minitrack stations such as Blossom Point, Maryland; Fort Myers, Florida; and Goldstone, California.

Initial Results

Acquisition of telemetry data from Explorer XII has been satisfactory, and during the 100%-coverage period (through November 1961), approximately 3000 magnetic tapes (each 2400 feet long) per month were recorded by the Minitrack network. It was planned to reduce coverage to 25%

in December, subject to technical requirements. Only one-third of the data tapes can be processed as received, but a statistical sample of the telemetry records is analyzed at that time. Data obtained near the time of more-prominent solar flares and magnetic storms have been given priority.

The principal investigators for the various experiments have reduced sufficient data to report that observed intensities appear to be within the expected ranges. Data from the ion-electron-detector experiment indicates a definite termination of the outer edge of the outer Van Allen region.

Between August 15 and September 12, 1961, the spin rate of the satellite increased from 27.78 rpm to 28.63 rpm (approximately 2.7%). This increase has been attributed to the effect of solar-radiation pressure on the four solar paddles, which are pitched in the proper direction to aid

the spin rate when the sun is shining on the lower half of the satellite. This effect was expected to continue for the first 160 days following launch.

A major degradation in the output of the unprotected solar-cell test patch has been observed, totalling 50% from August 16 to 18, 1961, and an additional 35% from August 18 to September 14. No degradation was noticeable for the three covered test-cell patches.

The orbital parameters for Explorer XII have changed as a result of solar and lunar perturbations. By September 12, apogee had decreased to approximately 77,030 km (47,863 statute miles) and perigee had increased to about 447 km (278 statute miles). The increase of perigee and decrease of apogee is as predicted and does not compromise the one-year lifetime needed for the Explorer XII experiments.

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US Antarctic Meteorology during the IGY

Part II: Weather Central and Hallett and Byrd Stations

This is the second portion of a report based on a series of articles prepared by US Weather Bureau meteorologists who took part in the IGY Antarctic program. The series originally appeared in Weatherwise, a publication of the American Meteorological Society. Part I, covering the work at Little America and Amundsen-Scott South Pole IGY Stations, appeared in Bulletin No. 53, November 1961.

The Weather Central at Little America

During the planning of the IGY Antarctic Program, in early 1955, the need for a weather central in the Antarctic was recognized. Air operations and over-snow traverses required accurate weather forecasting and analysis to assure maximum safety for operating personnel. The weather central would also serve as a clearing house for all raw Antarctic weather reports. Such reports would be screened at the Antarctic weather central and then transmitted by radio to other weather services in the Southern Hemisphere to help improve and extend their weather analyses and forecasts.

The international IGY coordinating body, CSAGI, asked the United States to accept the responsibility of operating an Antarctic weather central during the IGY.

The US National Committee accepted and plans were made to locate the IGY Antarctic Weather Central at Little America V. In addition to US meteorologists, representatives from Argentina, Australia, France, New Zealand, South Africa, and the USSR participated in the program.

Before the IGY Weather Central could go into full operation, it was necessary to activate the Antarctic communications network, consisting of a "mother-daughter" relay system (Fig. 1). On a prearranged schedule, a mother station collected weather reports from a number of daughter stations, then relayed these reports to the radio central at McMurdo Sound, where they were again collected and relayed to the Weather Central. After a delay owing to damage of the McMurdo antenna field by a blizzard in mid-May of 1957, the mother-daughter network went into full operation in late June. In addition to receiving weather reports from Antarctic stations on a regular schedule, weather data broadcasts from Southern Hemisphere countries were also intercepted at Weather Central.

The Weather Central analysis program included preparation of four surface charts; two 700-, 500-, and 300-mb constant-pressure charts; and one 50-mb constant-pressure chart per day. Pseudo-adiabatic charts

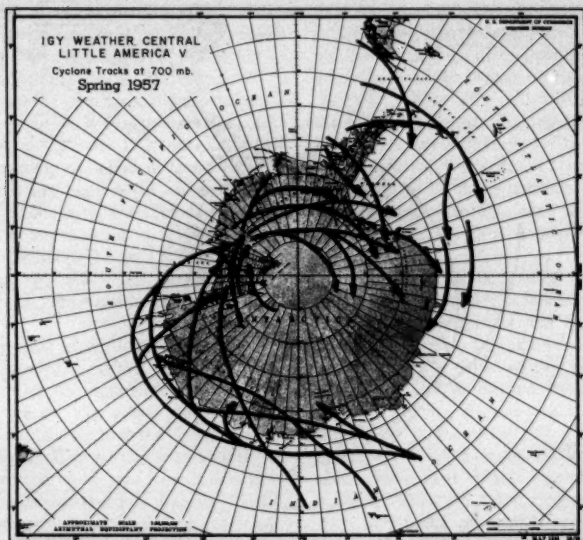


Fig. 2. Cyclone Tracks at 700-mb Level over Antarctic, Autumn 1957. Because of the high average elevation of the Antarctic interior, weather at the 700-mb pressure level (about 10,000 feet) is very nearly surface weather over the extensive continent. (Prepared by V. I. Rastorguev and J. A. Alvarez, Antarctic Weather Central, 1957.)

intense frontal systems are capable of maintaining their identity all the way to the Pole. Temperature contrasts across the fronts weaken as the air mass is modified during its movement over the extensive Antarctic ice sheet. Generally, only the upper remnants of a frontal system are evident by the time they reach the Pole, but they are still sufficiently intense to cause cloudiness and precipitation.

Preliminary atmospheric-circulation studies made by V. I. Rastorguev (USSR) and J. A. Alvarez (Argentina), who worked at the Weather Central in 1957, indicate that the interior of West Antarctica may be a more stormy region than the high interior of East Antarctica. As shown by the 700-millibar cyclone tracks for autumn and spring of 1957, (Figs. 2 and 3, respectively)

a major storm path exists from the Ross Sea through Marie Byrd Land and the Ellsworth Highland into the Weddell Sea. Cyclones moving along the coast of East Antarctica usually did not penetrate deeply into the interior until they reached Wilkes Land. The presence of a semi-permanent anticyclone over the high interior plateau tended to block the entry of the cyclones until they had passed the 90° E meridian.

The comparative freedom of the interior of East Antarctica from storms and cloudiness helps make it one of the coldest places on earth (see Fig. 1, *Bulletin No. 53*). Because of the high elevation of this region, averaging 10,000 feet above sea level, clear skies permit a large amount of heat to escape from the surface through the dry, transparent atmosphere. Record low tem-

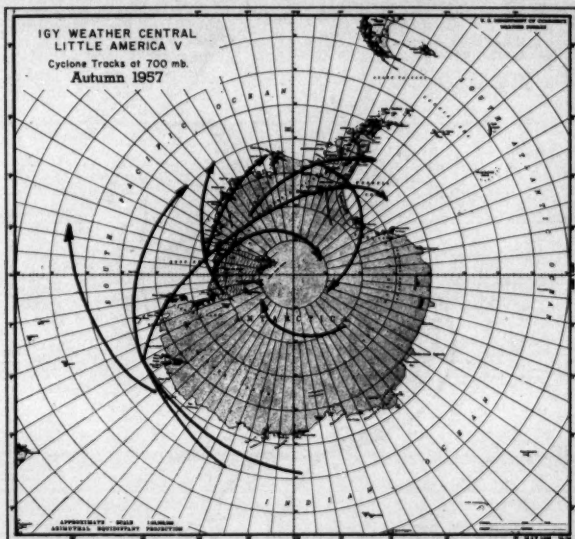


Fig. 3. Cyclone Tracks at 700-mb Level over Antarctic, Spring 1957. (Rastorguev and Alvarez.)

peratures have been reported by the USSR stations located in this high, interior plateau area: the lowest to date was -88.3°C (-126.9°F), at Vostok (78°S , 107°E , elevation 11,200 feet), August 24, 1960.

In addition to the frequent radio fade-outs, operational problems resulted from the limited working space, confinement, and rigorous climate. Despite the often severe working conditions at Little America Station, however, much valuable experience was gained and substantial results were achieved by the IGY scientists of the first Antarctic Weather Central.

Hallett Station

Located on Cape Hallett, a flat, barren promontory, slightly above sea level at the southern end of Moubray Bay and at the foot of the Admiralty Range on the west-

ern margin of the Ross Sea, Hallett Station was operated jointly by a small party of United States and New Zealand personnel during the IGY. Although Hallett had a meteorological staff of only four, its weather-observation program was nearly as extensive as those of the larger stations. Because of its location on the air route from New Zealand to the US Naval Air Facility at McMurdo Sound, Hallett Station has served, both during and since the IGY, as a key point in flight planning and navigation for this vital route.

Two years of IGY climatic records were obtained at Hallett Station. The mean annual temperature for each of these years—1957 and 1958—was $+4.6^{\circ}\text{F}$, and the extreme temperatures were $+42^{\circ}\text{F}$ and -44°F . The annual temperature regime shows an anomaly in June, when cooling is temporarily halted. July is the coldest month,

just a little colder than August, and the mean temperature in the Hallett region gradually rises from the mid-winter low to a peak in January.

In June, the stormiest month, average wind speed is at a maximum. The mean wind speed in 1957 was 17 knots and in 1958 it was 15 knots. Masked in these averages are alternating periods of calm or near-calm days, followed by periods of strong winds. The mean wind speed for October was only 12 knots but, in 1957, a three-day storm late in this month had sustained winds of 80 knots and a peak gust of 99 knots.

The location of Hallett Station, oriented NE-SW at the seaward end of a "V"-shaped valley, is important in considering its wind regime. The valley and the water-ice floor widen toward the Ross Sea and the northeast. Beyond the southwestern extremity of the valley, the terrain begins its gradual rise to the ice-covered Victoria Land plateau, where elevations reach 8000 to 10,000 feet a few hundred miles inland. This topographic setting favors the observed constancy of wind direction—prevailing from the southwest—at Hallett Station.

A notable deviation from the annual prevailing wind direction occurs in December. Beginning in late November and continuing into December of 1958, there was a distinct sea breeze, resulting in a prevailing northwest wind. Sea breeze, tide, and ice movement were rather closely related during this period. Shortly after the onset of the sea breeze and the beginning of the diurnal tide, loose ice began drifting from the Ross Sea into Moubray Bay.

The precipitation pattern at Hallett Station is closely connected with the wind and with general storm conditions. During the IGY, a period of strong winds always appeared to follow a snowfall, and a general temperature rise either preceded or accompanied the fall of snow. As is usually the case, it was extremely difficult to determine accurately when the falling snow ended and

the blowing snow began. Examination of the precipitation record for the two IGY years discloses a late-summer—early-fall maximum, with another near-maximum during the early winter. This indicates a continental type of precipitation regime, but with some maritime influences. With respect to this conclusion, the storm of October 20–22, 1957, mentioned above, appears anomalous. It is interesting to note that 1958 had approximately 25% less precipitation than 1957.

During periods of strong winds, snow cover on the ground was sparse. Except for drifts around buildings and in doorways, and snow coming through small cracks in the walls, snow cover was not too great a problem at Hallett Station. Movement out-of-doors during periods when snow was driven by high winds, however, was extremely difficult. During the October 1957 storm, movement outside was virtually impossible. Early warming had softened the bare and rocky ground. Flying debris included small rocks and gravel, and windward-facing surfaces were abraded severely. Wooden objects commonly took on a granular appearance and a windshield was so pitted that replacement was necessary. In 1958, there were three storm periods when stout line was strung from building to building for the safety of personnel, and a plan for checking in and out via the "tele-talk system" was also initiated.

The prediction of severe storms seemed to hinge upon the appearance, at the 500-millibar level, of a northeasterly air flow. This local forecasting guide was subsequently studied further and expanded to include the "rule of thumb" that the depth of the northeasterly flow would be an indication of the severity and duration of the storm—the deeper the flow, the stronger and longer-lasting the storm.

An emergency landing strip was also maintained on floating ice near Hallett Station. During the last half of 1958, there never appeared to be any danger of the strip moving out to sea. The maximum

thickness of the ice was about 76 inches, and the last measurement, about mid-December, showed an upper layer of 26 inches of dry ice above 40 inches of wet ice.

As in nearly all mountainous regions, some unusual cloud formations were observed. The clouds at Hallett were "lenticulars." The most spectacular of this variety, consisting of many layers of lens-shaped masses, was seen over Cape Roget. In appearance, it was similar to the one reported in 1958 over Mt. Rainer, by R. J. Reed. From the viewers' vantage point, the Hallett cloud appeared dark, but this may have been due to available light conditions, since other lenticulars were the usual white. It was noted during 1958 that Cape Roget seemed to be a favored location for the formation of these clouds. Others formed occasionally as "scarf" clouds around Mt. Herschel, about 17 miles directly west of the station. Mt. Herschel reaches a maximum height of about 11,500 feet above sea level, while elevations in the Cape Roget area do not exceed 4000 feet.

Towering cumulus clouds also would form over this high region (Cape Roget) to the north. Bases of these clouds were estimated at about 4000–5000 feet, with tops close to 15,000 feet. No direct reports regarding heights of the tops were available, however. The trail party from the interior, in February 1958, reported towering columnar cumulus clouds that formed rapidly over snow-free areas.

The final six months of the IGY period produced some interesting solar-radiation data. During late November 1958, radiation received over approximately a 20-hour daylight period with nearly clear skies was found to be about the same as that received at a Southwestern United States desert station under about the same conditions—800 langleys per day (1 langley equals one gram-calorie/cm²). The radiation instruments were located in an area where the surface varied—i.e., new snow, old snow, bare ground—and albedo measurements for the various types of surface cover at Hallett

Station agree with the generally recognized normals for such surfaces.

Soil temperatures at Hallett were taken at depths of 10 and 50 centimeters. The thermohms, buried close to the solar-radiation equipment, were completely drifted over by July 1958. The first months of record give temperatures under a gradually deepening blanket of snow, which reached a thickness of five feet before being bulldozed off in August. The removal of this blanket resulted in a sharp temperature drop. At 50 cm, temperatures approached the freezing point but did not rise above it, indicating that permafrost (permanently frozen ground) existed in the measurement area at this depth below the surface.

In December 1958, a thermograph was installed over a moss area east of the camp to measure the temperature environment of these plants. The sensing unit, approximately 1/4-inch above the moss surface and perpendicular to the prevailing southwest wind, recorded a temperature high of 68° F. In April 1959, a balloon-borne radiometer program, conducted jointly with similar studies at the South Pole Station, was begun in order to measure radiative cooling during the polar night.

The results of these and other observations made at Hallett Station, including some instituted since the IGY period, may be of considerable ultimate significance, both in basic meteorological studies and in providing better weather advice for traffic between Antarctica and New Zealand.

Byrd Station

The broad, wind-swept snow plateau of Marie Byrd Land, at 80°S, 120°W, is the site of Byrd IGY Station. One reason for the choice of this location was to investigate the puzzling atmospheric-pressure surges that occur in West Antarctica. First noted and described by G. C. Simpson, meteorologist with the British Antarctic Expedition of 1910–13, they were thought to originate at about 80°S, 120°W, and move

northwestward across the Ross Ice Shelf. Prior to the IGY, Antarctic data were not sufficient to determine the extent and causes of these pressure surges but the accumulation of additional data, begun with the IGY and still continuing, may shed further light on this problem.

Shortly after Byrd Station was established, seismic soundings showed that the relatively flat snow surface upon which the camp rested is the top of an 8000-foot thickness of ice, although this surface is only about 5000 feet above sea level. Thus, the bedrock surface is approximately 3000 feet below sea level in this region. The station lies near the track of cyclones that move onto the polar plateau from the Ross and Weddell seas, bringing intrusions of relatively warm maritime air and giving rise to stronger winds, heavier precipitation, and greater temperature fluctuations than might otherwise be expected at a location so deep in the interior of the Antarctic.

The relatively strong winds and frequent blizzards resulted in heavy drifting and accumulation of snow in the camp area, creating particular problems for the meteorological program. Among these were the need for a specially constructed tower for the radome housing the detection equipment for upper-air soundings; the frequent need

to clear snow from the overhead release doors of the rawinsonde balloon tower; and the necessity to dig out and re-position outside equipment, such as the instrument shelter, ceiling light projector, radiation instruments, and precipitation gauge.

Tables 1 and 2 present some of the surface data from the first three years of observations (including the IGC-59 period) at Byrd Station. The large year-to-year fluctuations in mean temperature for the same month are particularly striking. In August 1957, the mean temperature was -18.8°F , highest for any of the seven months from March to September; in August 1958, however, the mean temperature was -44.0°F , making it the coldest month of that year. In 1959, the mean August temperature was -38.8°F .

The warmth of August 1957 was related to the surface circulation regime in that month, when many pressure lows, with their accompanying warm maritime air, moved from the Ross Sea to the Weddell Sea along tracks over or very near Byrd Station. In August 1958, on the other hand, the storm tracks were well north of Byrd Station and cold plateau air predominated, a fact reflected also in the low precipitation in August 1958 as compared with August 1957. The temperature regime of August 1959 was

Table 1. *Temperatures ($^{\circ}\text{F}$) at Byrd Station in 1957, 1958 and 1959.*

Month	Mean			Maximum			Minimum		
	'57	'58	'59	'57	'58	'59	'57	'58	'59
Jan	+ 4.1	+13.3	- 0.8	+22.3	+23.7	+14.4	-21.3	-11.0	-17.7
Feb	- 6.2	- 5.2	- 1.8	+11.5	+19.4	+16.0	-34.8	- 3.6	-10.8
Mar	-22.9	-18.4	-13.7	- 0.9	+ 7.9	+ 7.9	-40.1	-53.1	-44.0
Apr	-32.4	-23.4	-11.0	+ 0.1	+15.4	+19.0	-68.1	-65.4	-49.2
May	-32.4	-18.9	-28.5	+19.6	+12.0	+18.1	-66.5	-66.6	-65.9
June	-28.3	-41.4	-27.0	+ 3.6	- 3.6	- 5.1	-70.4	-75.5	-54.8
July	-41.3	-41.3	-29.9	- 5.1	+13.5	+ 7.2	-69.9	-81.8	-66.3
Aug	-19.8	-44.0	-37.8	+ 8.2	+ 0.9	- 4.7	-51.3	-80.0	-70.1
Sep	-23.1	-40.2	-32.4	+ 1.4	- 6.0	- 2.6	-61.4	-65.0	-64.5
Oct	-15.0	-22.2	-30.1	+11.8	+ 5.0	- 2.9	-54.8	- 9.2	-59.1
Nov	- 5.1	- 5.6	- 8.7	+24.1	+10.4	+13.8	-28.5	-28.1	-38.9
Dec	+10.2	+ 1.0	+ 5.2	+24.1	+27.1	+17.1	-13.4	-21.8	- 9.0
Year	-17.7	-19.7	-18.0	+24.1	+27.1	+19.0	-70.4	-81.8	-70.1

Table 2. *Winds and Precipitation at Byrd Station in 1957, 1958, and 1959.*

Month	Prevailing wind direction and speed (knots)			Fastest wind (mph)			Precipitation (inches of water equivalent)		
	'57	'58	'59	'57	'58	'59	'57	'58	'59
Jan	N 10.5	NNE 13.1	NNE 12.0	28	32	36	1.24	.43	.06
Feb	N 12.5	NNE 18.7	N 13.6	31	58	40	.77	T*	.39
Mar	NE 17.2	N 14.0	NNE 15.7	42	M	53	.86	.08	.03
Apr	NNE 17.3	NNE 14.9	N 14.3	43	52	52	.72	.29	.14
May	NNE 16.5	NNE 19.0	NE 15.5	34	61	59	.96	.21	.13
June	N 15.5	N 12.3	NNE 17.1	47	44	60	1.97	.01	.12
July	NNE 19.0	N 15.7	N 16.3	45	63	67	2.73	.03	.10
Aug	N 23.5	NNE 15.9	NNE 18.6	62	61	59	1.50	T	.12
Sep	NE 22.5	NNE 20.0	NE 18.4	46	58	63	2.79	T	.09
Oct	N 15.0	NNE 18.6	NE 14.9	44	52	45	3.24	.03	T
Nov	NE 16.5	NNE 17.1	NNE 14.3	42	58	41	.05	T	T
Dec	N 13.4	NNE 13.3	NE 11.5	50	40	36	.05	.65	.03
Year	N 16.6	NNE 16.1	NNE 15.2	62	63	67	16.88	1.75	1.21

*Trace amount

similar to that of August 1958. Temperatures in August 1957 also fluctuated rapidly on a day-to-day basis, reaching $+8.3^{\circ}\text{F}$ on the 29th and then dropping rapidly to a low of -51.2°F on the 30th.

As shown in Table 2, winds at Byrd Station, prevailing from the north-northeast, average about 15 knots and reach gale force in nearly every month. It was observed also that winds of 20 knots or greater (which occur more than 2/3 of the time) are sufficient to start the snow drifting and that winds of 30 knots or greater (which occur about 1/3 of the time) result in blizzard conditions with near-zero visibility. Thus, the problem of drifting snow was worse at Byrd than at any other US scientific station in the Antarctic.

There was evidence, at times, of an apparent katabatic (downslope) wind flow at Byrd Station, particularly during the winter of 1958. Traverse parties have determined that the surface elevation rises gently north-northeastward from the station and falls toward the southwest—for a total drop of about 4000 feet in 300 miles; the prevailing winds are from north to northeast throughout the year. During periods of clear weather, there were times when a fairly brisk northerly wind (15–20 knots)

decreased to almost calm about 1500 feet above the surface. Thus, it seems probable that, when clear skies extend toward the north, the additional radiational cooling at the slightly higher elevations in that direction from the station would be enough to create a relatively colder layer of air near the surface, which would then flow downslope (southward) as a gravity wind.

When blizzard conditions occurred at temperatures lower than about -30°F at Byrd Station, a high static electricity charge was seen to build up on buildings and guy wires, with brilliant blue-white arcing visible during the dark period. The static sometimes seriously impaired radio communications, and also presented a danger to those working with the inflammable hydrogen used to inflate the radiosonde balloons, although no mishaps occurred.

The lowest temperature recorded by upper-air soundings during 1957–58 was -83°C (-135°F), on July 20, 1958. In winter, particularly in July and early August, the tropopause tended to weaken, or even disappear entirely; with the return of the sun, it again became easily identifiable, usually between the 300- and 200-millibar levels (approximately 30,000–38,000 feet). The pattern of rapid spring stratospheric

warming noted at other Antarctic stations also prevailed at Byrd Station. In 1957, temperatures at a height of about 12 miles above sea level (50-millibar pressure level) rose from -70°C (-94°F) in mid-October to -27°C (-17°F) by November 6, an increase of over 75°F in less than a month. In 1958, warming was similar but slightly less pronounced, with 50-mb temperatures rising from -70°C in mid-October to -30°C by November 10.

Extremely brilliant optical phenomena, many caused by ice crystals at low levels, were also observed at Byrd Station. Double halos and parhelia were common, and both tangential and circumzenithal arcs occurred frequently. (Halos appear as colored or

whitish rings and arcs about the sun or moon and are produced by refraction by or reflection from ice crystals in the atmosphere. Parhelia are colored, luminous spots 22° or more laterally from the sun; tangent and circumzenithal arcs are types of halos, the former tangent to other halos and the latter usually appearing about 46° above the sun.)

One of the most interesting of these optical displays occurred in May 1958, when a combination of ice crystals aloft and a water-droplet fog to the south caused a bright halo around the full moon as well as a circumzenithal arc, which, to the south, intersected a moonbow (rainbow formed by moonlight).

International Geophysical Calendar, 1962

The following is taken from a brief explanatory text accompanying the International Geophysical Calendar for 1962, issued by the International World Days Service, A. H. Shapley, Spokesman. The 1961 Calendar, accompanied by an expanded text describing its purpose and how it is used, was published in Bulletin No. 42. A report on the plan for Alerts and Special World Intervals during 1961-62 appeared in Bulletin No. 47.

The International Geophysical Calendar for 1962 (Fig. 4) designates selected days and intervals for special geophysical experiments and analyses during 1962, and is thus a framework for world-wide coordination. It serves mainly those branches of geophysics dealing with atmospheric phenomena that vary significantly during the course of a year. For some studies, such as the routine recording of geomagnetic-field variations, the programs of observatories are normally carried out at a uniform level throughout the year, and the Calendar is

therefore not needed. However, in many other studies—rocket experiments, for example—in which it is not practical or meaningful to carry out the same program every day, the Calendar can provide a useful mechanism for international coordination. Experimenters in many countries, laboratories, and disciplines tend to carry out their experiments on days or intervals marked on the Calendar. Results may then be more easily and usefully compared.

In some scientific fields, international organizations have made specific recommendations for investigations on days or intervals marked on the Calendar. In others, the arrangements are informal or self-evident. Some examples are given below.

Regular World Days (RWD)

These days (three consecutive days each month) are intended for observations, analyses, or special experiments which, as a practical matter, can be carried out only about 10% of the time and should, for



Fig. 4. IWDS International Geophysical Calendar for 1962.

maximum usefulness, be spaced evenly throughout the year. The RWD's with highest priority are for similar kinds of studies that can be undertaken for only one day each month.

World Synoptic Intervals (WSI)

These Intervals are intended for experiments which, for practical reasons, cannot be performed continuously, but for which

statistics of seasonal variations are especially needed. To simplify the Calendar, the Regular World Intervals, World Meteorological Intervals, and International Rocket Weeks of past years have been combined for 1962 into this one set of WSI. For purposes of the synoptic meteorological rocket programs, as designated by COSPAR and WMO (see *Bulletin No. 40*), the Intervals have been placed about a month after the equinoxes and solstices—

the times of marked seasonal change in certain upper-air meteorological phenomena.

During WSI, meteorological rockets are launched at least once daily over a network of stations. Balloon sounding programs, either with special instruments or involving launchings to unusually high balloon altitudes, have been planned for WSI. Ionospheric-drift and high-atmosphere-wind measurements, are other examples of suitable programs for such Intervals. In several disciplines, WSI data will provide a sampling of variations throughout the year, but with improved statistics during one month of each season.

Other Special Days

Also marked on the 1962 Calendar are other special days, including the days of solar eclipses (two in 1962 and one in January 1963), when special programs may be expected to be carried out in appropriate parts of the world to study the sun and any eclipse effects on the earth's atmosphere. Ionospheric stations customarily increase their observing programs on these days, even if the magnitude of the eclipse at their locations is small, and many solar-activity observatories make extra observations and issue specially detailed reports to assist in interpretation of the geophysical effects.

Also shown on the Calendar are days when unusual meteor-shower activity is expected. These include some of the important visual meteor showers and also unusual showers observable mainly by radio and radar techniques. Attention is called to these days also because ionization produced by meteors may account for unusual effects in other geophysical experiments.

The Annual World Meteorological Day, scheduled for March 23 but not marked on the Calendar, was first held in 1961. Its purpose is to make the activities of the

World Meteorological Organization, and the services that national meteorological services can render to the various branches of economic development, better known and appreciated by the public.

Other Special Intervals Not Appearing on Calendar: Periods of great magnetic, aural, and ionospheric disturbance are also of considerable geophysical interest. World-wide coordination of observations is especially useful for stations not near the aural zones, i.e., those at which the beginning of a major disturbance may not be immediately apparent from local observations. Notices of Geophysical Alerts and Special World Intervals (SWI) are distributed by telegram or radio broadcast on a current basis by the solar-geophysical Regional Warning Centers. (See *Bulletin No. 47* for addresses of these Centers and for details of the aims, functions, and methods of operation of the World Warning Agency.)

Many geophysical stations increase their programs or carry on special experiments during such periods of solar-terrestrial disturbance. Prompt notification of immediately significant geophysical observations and of major solar-flare events having important and sometimes long-lasting geophysical effects are also undertaken through the Regional Warning Centers.

Additional Information

The 1962 Calendar was drawn up by A. H. Shapley and J. V. Lincoln, of the US National Bureau of Standards, Boulder Laboratories, Boulder, Colorado, in consultation with interested ICSU unions and committees and representatives of the WMO. A fuller description of the Calendar has appeared in the *U. R. S. I. Information Bulletin* and in various widely available scientific publications. Supplementary copies may be obtained from the Secretary General of URSI, 7 Place Emile Dancó, Brussels 18, Belgium.

Biological Oceanography in the North Polar Sea from IGY Drifting Station Alpha, 1957-58

The following material, prepared by the Bulletin staff, is based on a report by T. Saunders English, Department of Oceanography, University of Washington, entitled *Some Biological Oceanographic Observations in the Central North Polar Sea, Drift Station Alpha, 1957-1958, and published by the Arctic Institute of North America as its Research Paper No. 13 (also as Air Force Cambridge Research Laboratories Scientific Report No. 15, AFCRL-652), April 1961.*

Because only a very limited amount of light is available to the Arctic Ocean submarine environment, primary production—the production of phytoplankton, simple forms of floating plant life that provide the basic food resource for marine animal life—is very low compared to that in other oceans, and the productive season is short. For these reasons, and because of the remote, rigorous, and hazardous nature of the Arctic Ocean area, substantial gaps have existed in our knowledge of its marine life. Thus, when the establishment of a US-IGY scientific station on Drifting Station Alpha provided the opportunity, a series of biological oceanographic observations was conducted in the central Arctic Ocean during the period of occupation of the station, April 1957-November 1958. Major aims of these investigations were to study various aspects of primary productivity and to obtain, in water bottles, a series of samples of Arctic Ocean phytoplankton in their natural environments.

(Earlier *Bulletins* report on Station Alpha programs and results, and include maps showing its drift path; *Bulletin No. 17* provides some background on the marine biology studies, and *Bulletin No. 27* reports on similar studies on IGY Drifting Station Bravo, elsewhere in the Arctic Ocean.)

The Ice Flow Environment

Drifting Station Alpha was located on a large ice floe in the permanent Arctic ice pack. The station's course during its period of occupation remained in about the center of the Arctic Ocean, near the "Ice Pole," or "Pole of Inaccessibility." Floes of the permanent ice pack average about 2.5 meters thick; ridges of broken ice (hummocks), mostly up to 3 meters high, may reach 10 meters. Much of the floe area near Station Alpha was 3 meters thick, and small areas were observed during dives beneath the floes (using self-contained underwater breathing apparatus) in which several thicknesses of floe reached a depth of about 15 meters. Little change in thickness was seen during the melt season as ablation was slight: 7-10 cm in 1957 and 30 cm in 1958.

Leads—channels of open water between the floes—have been estimated to constitute only about 1% of the total surface area within the ice pack. The first lead examined in the Station Alpha studies opened on June 15, 1957, and its surface ceased to freeze in late June. At the end of August, slush began to form in open leads. There is less open water toward the center of the ice pack and progressively more toward the outer edges. For more than 10 months of the year, the floe ice is covered by wind-packed snow. Ablation begins after the return of the sun each year, eventually removing the snow cover and melting some of the floe ice, leaving a granular ice surface.

Melt-water ponds appeared on the floes in early July in both 1957 and 1958 and eventually covered 15-30% of the surface area. The melt water runs off the floes into cracks and leads, forming a surface layer of nearly fresh water 1-2 meters deep; the thickness of this layer varies with the size

of the watershed, intensity of melting, floe movement, wind-driven mixing with the underlying sea water, and extent of the leads. Pond surfaces froze in late August and the entire area became covered with the snow of the new winter. Investigation of the effects of these seasonal changes on the biological and hydrographic cycles was a major part of the field studies.

Vertical Distribution of Water Masses

The details of surface and deeper circulation of the North Polar Sea have been rather fully described by earlier workers. Results from IGY Drifting Station Alpha agree with these descriptions and add some details to our knowledge of the surface water mass. Temperature and salinity, and the derived density, may be used to differentiate the water masses (Fig. 5). The uppermost layers consist of Arctic Upper Water, of low salinity and temperature, and, below it, Arctic Intermediate Water, with generally increasing temperatures and a sharp halocline (zone of rapidly increasing salinity, and of density, just below the surface layers) ranging from about 31 per mille (31 parts per thousand) at a depth of 50 meters to more than 34 per mille at 200 meters. Warmer Atlantic Water, bounded at its upper and lower surfaces by the 0° C isotherms, lies below the Arctic Intermediate Water and above the Arctic Deep Water, which extends to the ocean bottom.

A Pacific Ocean Water stratum, intruding between the Arctic Upper Water and Arctic Intermediate Water, having an estimated temperature range of -0.7 to -1.2° C and a salinity of about 32 per mille, was recognized a few years ago. More recently, it has been suggested that the intrusion of Bering Sea Water into the Arctic Ocean, and the mixing of this water with appropriate amounts of shelf water in summer and winter, is responsible for both the temperature maximum in the North Polar Sea (here, at 75-100 meters) and the

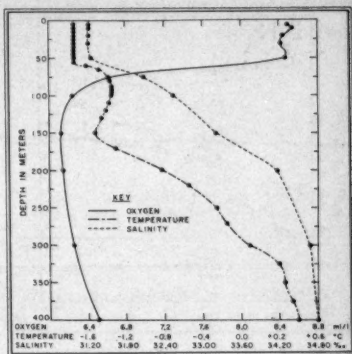


Fig. 5. Temperature, Salinity, and Dissolved-Oxygen Variation with Depth, Drifting Station Alpha, June 23-24, 1958.

temperature minimum below it (here, at 150 meters). This interpretation is strongly supported by the vertical distribution of dissolved oxygen and of inorganic nutrients observed from Station Alpha (Figs. 5 and 6).

The vertical homogeneity of observed oceanographic variables in the Arctic Upper Water, as well as the rapid attainment of uniform temperature and salinity with depth, indicate that mixing in this stratum is rapid and complete. Nutrient enrichment of the Arctic Upper Water must proceed very slowly, however, as the pronounced halocline is a strong barrier to upward mixing of nutrients from the maxima observed at 100-150 meters in the Pacific Ocean Water (Fig. 6). Also, a persistent temperature minimum (about -1.7° C) between the Arctic Upper Water and the Pacific Ocean Water, seen in temperature profiles for 1958, suggests that there is no mixing across that isotherm during the summer, although in some years this barrier may be broken.

Seasonal Cycles

As summer progressed, salinity decreased slightly in the Arctic Upper Water (several

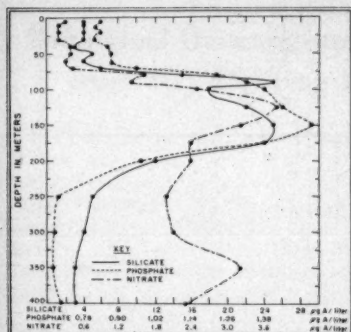


Fig. 6. Variation of Inorganic-Nutrient Concentrations with Depth, Drifting Station Alpha, August 19, 1958.

tenths of 1 per mille), temperature increased slightly (several tenths of 1°C), dissolved oxygen increased, and the amount of solar radiation penetrating into the ocean increased very noticeably. If it is assumed that the size of the phytoplankton population can be estimated from the concentration of chlorophyll *a*, the population was ten times as large in late July and early August as it was in early June. (Chlorophyll *a* is the first photosynthetic pigment to develop when light is supplied in a dark environment.) Carbon-14 experiments using samples representing most of the 1958 productive season indicate that the photosynthetic potential of the phytoplankton varies in a manner similar to that of the chlorophyll *a* concentration. The observations were inadequate to demonstrate any decrease in inorganic nutrients caused by the production of phytoplankton.

Previously, in studies near the periphery of the permanent ice pack northeast of Greenland, seasonal variations in phytoplankton concentrations were noted only in the upper 25 meters, which is in accord with other observations showing that Arctic Upper Water extends to a depth of 20–30 meters in southern parts of the sea

and 50–75 meters in the north. Seasonal changes were also noted in the zooplankton (floating or weakly swimming, minute animal life), which remained in the "winter state" in July. The exceedingly short productive season makes this an extreme example of a monocyclic sea.

Station Alpha results indicate that the seasonal cycle occurred to a depth somewhat below 50 meters, and results from Fletcher's Ice Island (A. E. Collin, 1959, and J. S. Farlow, 1958) and from the Soviet station North Pole II show a similar layer over a large portion of the North Polar Sea. Complete mixing of the Arctic Upper Water ensures that this seasonal cycle will be evident to whatever depth the layer extends in other areas.

Incident and Submarine Solar Radiation

Daily insolation, or incident solar radiation, even as far south as 70°N , is negligible from early November to early February. It increases rather uniformly into May, reaches a maximum about June 21, and then decreases through the summer and autumn. The seasonal trend of visible radiation at Drifting Station Alpha was clear despite a variability related to differential cloud cover (Fig. 7).

The amount of visible radiation available for photosynthesis beneath the ice is increased by the occurrence of leads, by ablation of the snow cover, by decrease in ice-floe thickness, by formation of melt water ponds on the floes, and by decrease in the albedo (percentage of incident radiation that is reflected) of the ice surface. In June, before the snow cover had disappeared, less than 1% of the surface radiation penetrated through an average ice floe into the sea. Removing a layer of snow only a few centimeters thick more than doubled the amount, and wetting the surface increased it still more. In mid-July, the radiation under a pond was about five times as high as that under ordinary ice-floe areas.

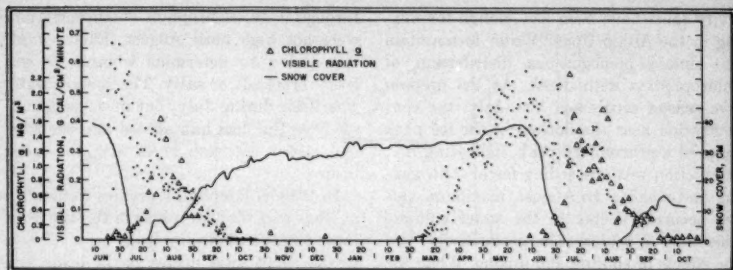


Fig. 7. Comparison of Visible Radiation, Snow Cover, and Chlorophyll *a* Concentration, Drifting Station Alpha, 1957-1958.

Submarine radiation was measured at successive depths, both in large leads and beneath ice floes. The vertical distance between equal radiation intensities provides a rough measure of the depth by which the zone in which plants thrive is changed from one environment to the other. It appears that an average floe reduces this depth to less than one-half that of the freely convective layer of Arctic Upper Water.

The snow cover vanished in early July, greatly increasing the amount of light entering the sea (Fig. 7) and more than compensating for the decrease of sunlight at the surface following the peak about June 21. Maximum penetration of light into the sea must occur shortly after the formation of ponds on the floe surfaces.

The decrease in submarine radiation in August is quite abrupt, and is caused by the lowering of the angle of incidence of solar radiation and an increase in albedo brought about first by freezing of ponds and leads and finally by the new snow cover.

The fact that chlorophyll *a* increased, and reached maximum concentration, after the widespread formation of melt-water ponds and while the final traces of snow were disappearing, confirms the belief that photosynthesis under the ice pack is limited by the lack of sufficient solar radia-

tion. The role of the ice pack in regulating the amount of solar radiation penetrating into the sea is also clear. This amount must depend, during a productive season, on the proportions passing through leads and floes, with or without ponds or snow cover; on seasonal, diurnal, and meteorological variations; and on the variability of the ice cover and its movement relative to the ocean. Thus, the history of the radiation received by any small volume of sea water is always in doubt, and some of the unusually high and low chlorophyll *a* values obtained can probably be explained by a radiation history widely divergent from the average.

Distribution of Chlorophyll *a*

Seasonal variations in chlorophyll *a* concentration were followed through two productive seasons and the distribution with depth was considered for periods throughout the 1958 season. Figure 8 shows this distribution in the depth range of 4-64 meters. In samples collected at depths of 128 and 256 meters, only traces were found.

The shapes of the concentration curves must reflect the balance between production and both mixing and sinking of the phytoplankton cells. Before June, produc-

tivity must have been low enough for mixing in the Arctic Upper Water to maintain an almost homogeneous distribution of chlorophyll *a* with depth. As the productive season progressed into July, the concentration near the bottom of the ice pack reached a pronounced peak, indicating that production was proceeding faster than mixing and sinking. In August, maximum values occurred deeper in the water column, reflecting a decrease in productivity and the effects of sinking and mixing. When the productive season was over, the concentration of chlorophyll *a* in the water column was again almost homogeneous.

Plankton Samples

During each week of the productive season, a phytoplankton sample was concentrated in a net for comparison with a routine sample taken with a molecular filter. The net retained only trace quantities of chlorophyll *a*, and at the time of maximum concentrations the amount captured by the net was less than 10% of the amount retained on the filter. A preliminary examination of preserved samples indicates that few large diatoms were present but that small flagellates were numerous. This result was expected on the basis of previous work by others.

Production in Leads and Ponds

Earlier investigators suggested that the small amount of open water between ice floes was not of major importance to phytoplankton production in the North Polar Sea; it appeared necessary, however, to establish the relation of that water to the main body of the ocean.

In many samples taken in a lead, in 1957, the integrated concentration of chlorophyll *a* for a one m² water column extending from the surface to a depth of 5 meters was consistently about one-half the concentration found from 5 to 20 meters. Although the leads received strong sunlight

through July, chlorophyll *a* concentrations were not high until August. Each sample was tested to determine whether it was fresh, brackish, or salty. The surface water was fresh during July, but in August, runoff from the floes had abated and the wind had mixed the fresh layer with the ocean below.

In 1958, chlorophyll *a* profiles were taken in leads and through a hole in the floe. Surface concentrations in leads were always smaller than those deeper in the leads, and usually smaller than the concentration beneath the ice floes. Carbon-14 experiments in 1957 and 1958 showed a similar pattern of photosynthesis and photosynthetic potential with depth.

The low concentrations of chlorophyll *a* at the surface are thought to reflect the dilution of surface sea water with freshwater runoff, but inhibition of photosynthesis by strong surface light could also contribute to the observed effects. However, the high surface chlorophyll *a* concentrations in early August 1957, when runoff had diminished, suggests that dilution is the major factor. A single sample from a fresh-water floe-surface pond showed only a trace of chlorophyll *a*, and no color was ever seen in a pond. Although water in the leads sometimes attained high chlorophyll *a* concentrations and showed higher photosynthetic potential than water below the depth of the ice bottom, little effect of increased solar radiation through the leads was immediately evident.

On one occasion, a sample of what appeared to be a plankton bloom was taken with a large syringe during a dive through a lead. The concentration of chlorophyll *a* measured in the sample was well above that of the main body of the ocean at that time but similar to concentrations in other such areas in August.

E. H. Gran, reporting in 1904 on samples collected during the *Fram* expedition (the research vessel *Fram* crossed the Arctic Ocean basin frozen in the ice pack, in 1893-96) mentions free-floating lumps of

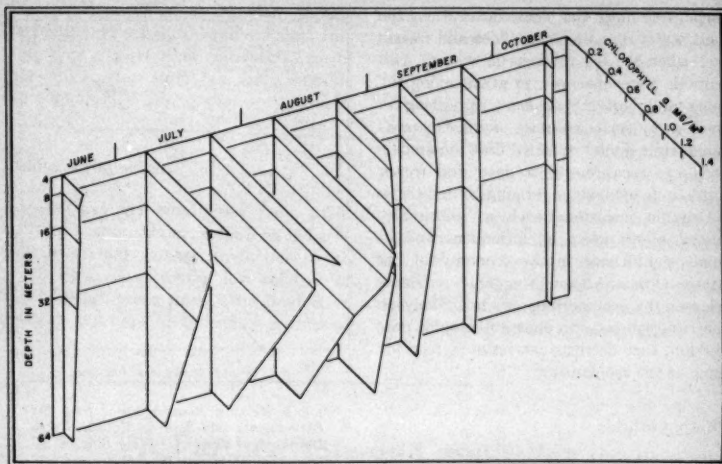


Fig. 8. Chlorophyll a Concentrations with Depth during 1958 Productive Season at Drifting Station Alpha.

planktonic algae in leads; diatoms on the "ice foot" (a ledge projecting from a floe just below the comparatively warm few cm of surface water, which more thoroughly melts away the overlying floe ice); and diatoms in cylindrical holes on floes, at the bottoms of fresh-water ponds not connected with the open sea.

In 1957, free-floating lumps of planktonic algae were observed near Drifting Station Alpha. In 1958, one area of ice foot was discovered in a persistent lead; clumps of diatoms on it had melted cylindrical holes into the ice. A few bleached clumps of diatoms were also discovered on the ice-floe surfaces and on the bottoms of ponds. No pigmented diatoms were found in these places, however, and it seems likely that the bleached clumps once floated in leads or were on the bottoms of floes, and that they then became frozen into floes and finally moved upward to the floe surfaces as the floes underwent ablation at the top and accretion at the bottom.

Inorganic and Organic Nutrients

Inorganic nutrients are less abundant in the Arctic Upper Water than in the Pacific Ocean Water, but there is no evidence that a shortage of such nutrients limits production in the North Polar Sea, since their experimental addition in carbon-14 experiments failed to lead to a significant increase in photosynthesis.

Trygve Braarud, in 1935, pointed out that the fresh water from melting ice is very low in nutrients, and would limit rather than increase plant production. In the Station Alpha studies, measurements made of inorganic nutrient from a pond, a lead, and at depths in the sea, also demonstrate that melt water can only dilute the Arctic Upper Water.

Films of organic matter, predominately diatoms, but probably including flagellates, ciliates, bacteria, and organic detritus, can be seen on the sides and bottoms of ice floes. These films must sometimes be in-

corporated into the floes, both when the melt water runs under the floes and freezes and when the ice thickens in winter. Amphipods were observed to graze along the sides and bottoms of floes, appearing to wear away small volumes of ice. Observations while diving revealed that the amphipods are occasionally trapped and frozen into a hole by new ice forming behind them.

Organic inclusions such as those discussed above must be infrequent and of small significance in the economy of the Arctic Ocean. Although organic nutrients released by ice melting are not likely to contribute directly to photoautotrophic production, such detritus can serve as food for some of the zooplankton.

Photosynthesis

The carbon-14 technique was used on 1957 samples to obtain a rough estimate of photosynthesis *in situ* beneath the surface of a lead. There was no measurable photosynthesis on July 1, but for late July and mid-August, it is estimated that, in a one-m² water column extending to a depth of 30 meters, 5-6 milligrams of carbon were assimilated per day. The water column in the lead above the bottom of the ice floes contributed about one-fourth to the totals.

In 1958, the photosynthetic potential of water from different depths was studied. The decrease of photosynthetic potential with depth was found to be similar to, but more rapid than, the decrease of chlorophyll *a* concentration with depth (Fig. 9). There are several possible explanations for this difference in rates of decrease: if phytoplankton from greater depths had become adapted to lower light intensities the illumination used in the experiments might then have inhibited photosynthesis; also, the proportion of photosynthetically inactive pigment (included here with chlorophyll *a*) might increase with depth.

Studies were conducted of the effect of different light intensities on 14 species of marine plankton algae from sub-samples

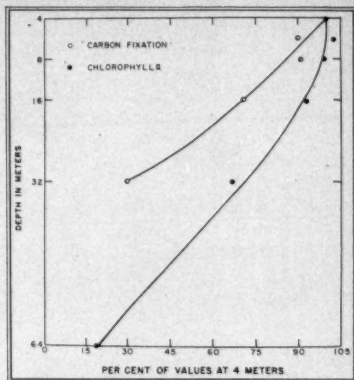


Fig. 9. Relative Photosynthesis from Six Experiments with Samples Collected at a Depth of 6 Meters, Drifting Station Alpha, July 20-August 13, 1958.

of water obtained at a depth of 6 meters. The compensation intensity (light-intensity level at which plant metabolism balances the energy produced by photosynthesis) was between 20 and 200 foot-candles and the saturation intensity (light intensity above which there is no further increase in photosynthesis) was near 2000 foot-candles. It seems especially significant that the phytoplankton population under the ice does not show adaptation to lower light intensities than do similar organisms from lower latitudes, examined previously by others.

A determination of the ratio of photosynthesis to chlorophyll *a* concentration in samples taken from a depth of 6 meters, on the same or consecutive days, gave a value of 0.6, considerably lower than the value of 3.7 obtained in studies by J. H. Ryther and C. S. Yentsch, in 1957. The lower ratio in the Station Alpha studies may result from the extremely low temperature of the Arctic Upper Water, which may reduce the efficiency of carbon fixation per unit of

chlorophyll *a*. (This explanation, though convenient, raises considerable doubt; further work, or another interpretation of these data, may supply a more suitable explanation.)

Annual Production

Investigations conducted from IGY Drifting Station Alpha in 1957-58 indicate that the annual primary production in the North Polar Sea is very low relative to that of other ocean areas. The productive season is short and all indices of productiv-

ity are low. The limiting amount of submarine illumination serves as a satisfactory first order explanation for this low level of primary production.

Because primary production in the North Polar Sea is so low, further refinements in methods of estimating the annual total appear unnecessary. The factors operating to produce and maintain a population of photosynthetic organisms under the extreme environmental conditions observed will continue to be of interest, however. In this report, the behavior and special adaptations of the phytoplankton population have been suggested rather than explained.

A Further Note on Cosmic-Ray Air Showers

A brief report entitled "Energetic Cosmic-Ray Air Shower," in *Bulletin No. 51*, September 1961, may contain an unintended implication that cosmic rays of extragalactic origin are exceedingly rare. The report describes an extremely energetic cosmic-ray air shower detected at the Massachusetts Institute of Technology cosmic-ray station, Volcano Ranch, New Mexico, and reports the investigators' conclusion that the primary cosmic-ray particle that caused the great air shower had an energy of 10^{19} electron volts, or more, and that it appears certain that this energy must have been acquired outside our galaxy.

A note in *Physical Review Letters*, May 1, 1961, by John Linsley, Livio Scarsi, and Bruno Rossi, served as the primary basis for the *Bulletin* report; although this note was not the source of statements possibly leading to this erroneous implication, Dr. Linsley, Director of the Volcano Ranch Station, has kindly offered the following further clarification, which expresses the

view of most current workers in this field: "If extragalactic cosmic rays exist, they probably exist in some quantity, with energies less than 10^{19} ev, as well as greater. Probably most of the cosmic rays with energies greater than 10^{18} ev (some would say 10^{17}) are also extragalactic. Extragalactic cosmic rays with energies lower than 10^{17} or 10^{18} ev, if they exist, would not be distinguishable from the background of cosmic rays of galactic origin."

The *Bulletin* report states, also, that "... the total number of particles [in the air shower] was at least 5.5 billion, and may have been 4 to 8 times that many." The estimate "4 to 8 times" resulted from an editorial error and should be corrected to read "... may have been twice that many."

Subsequent to the event discussed above, the Volcano Ranch Station, using a detector array covering about four times the area of the earlier array, detected a still larger and more-energetic cosmic-ray air shower. The Volcano Ranch investigators calculate

that this shower, which occurred in March 1961 and was the largest recorded as of that time, consisted of about 32 billion par-

ticles and was triggered by a primary cosmic-ray particle having an energy of 6×10^{19} ev.

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